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Technical Report

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NAVAL FACILITIES ENGINEERING COMMAND

November 1977

CIVIL ENGINEERING LABORATORY
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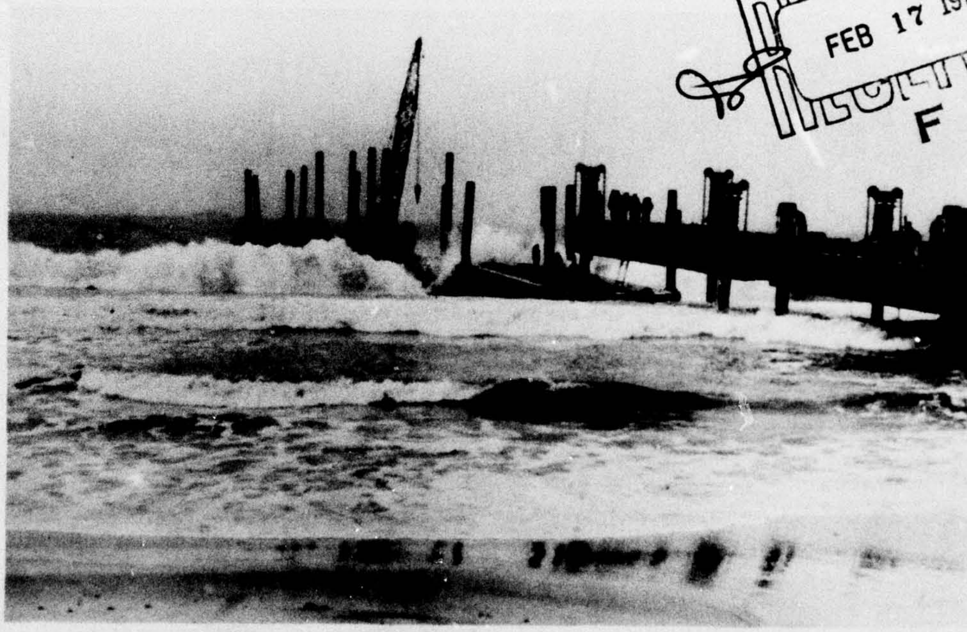

CONTAINER OFF-LOADING AND TRANSFER SYSTEM (COTS)

Advanced Development Tests of Elevated Causeway System

Volume II – ELEVATED CAUSEWAY INSTALLATION AND RETRIEVAL

by C. I. Skaalen and A. B. Rausch

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(16) Y0814, Y41X6

(17) Y0814SL, Y41X6001

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(14) (9)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: CEL TR-852[redacted]-2
2. GOVT ACCESSION NO.: DN587072
3. RECIPIENT'S CATALOG NUMBER: Technical rept. Jun 75-Jan 76
4. TITLE (and Subtitle): (6) CONTAINER OFF-LOADING AND TRANSFER SYSTEM (COTS) Advanced Development Tests of Elevated Causeway System. Volume II. Elevated Causeway Installation and Retrieval.
5. TYPE OF REPORT & PERIOD COVERED: Not final; Jun 75 – Jan 76
6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s): (10) C. I. Skaalen [redacted] A. B. Rausch
8. CONTRACT OR GRANT NUMBER(s):
9. PERFORMING ORGANIZATION NAME AND ADDRESS: CIVIL ENGINEERING LABORATORY, Naval Construction Battalion Center, Port Hueneme, California 93043
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 63719N; Y41X6-001-01-001
11. CONTROLLING OFFICE NAME AND ADDRESS: Naval Facilities Engineering Command, Alexandria, Virginia 22332
12. REPORT DATE: (11) Nov[redacted]77
13. NUMBER OF PAGES: 107 (12) 112p.
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):
15. SECURITY CLASS. (of this report): Unclassified
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:
16. DISTRIBUTION STATEMENT (of this Report): Approved for public release; distribution unlimited.
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report):

DDC

FEB 17 1978

F

18. SUPPLEMENTARY NOTES:
19. KEY WORDS (Continue on reverse side if necessary and identify by block number): Causeways, elevation, pontoons, piers, containers, unloading, cargo handling, off-loading, elevated causeway, lighters, containerization, lift systems.
20. ABSTRACT (Continue on reverse side if necessary and identify by block number):

A two-phase advanced development test program was conducted to evaluate the installation, operation, and demobilization of an elevated causeway system. This volume details the portion of the program dealing with the pier installation and retrieval. Pier installation and retrieval methods, lift system, pile positioning, driving and pulling techniques, site and elevated causeway surveys and survey methods, and utilization of associated lift over

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

391 111

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

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CONTAINER OFF-LOADING AND TRANSFER SYSTEM (COTS) – Advanced Development Tests of Elevated Causeway System. Volume II – Elevated Causeway Installation and Retrieval
TR-852 – II 107 pp illus November 1977 Unclassified

1. Elevated causeway 2. Containerization I. Y41X6-001-01-001

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SECTION 1

INTRODUCTION

1.1 SCOPE

The advanced development tests for the elevated causeway were performed to evaluate system hardware, using an adequate number of pontoon sections, existing military lighters and trucks, and 8 x 8 x 20-foot (2.4 x 2.4 x 6.1-m) commercial containers. The equipment tested included four specially assembled NL pontoon pierhead sections with internal spudwells, five existing pontoon sections equipped with external spudwells, a hydraulic lift system, two types of plastic foam fender systems, three types of Navy lighters, one type of Marine Corps tractor/trailer, a turntable, and two types of commercial container handlers. In addition, other selected hardware items were evaluated during the operation. Timing data were taken at pertinent points of the operation; however, this information was considered to be secondary to determining any operational limitations, proper procedures, and problems requiring further development efforts.

1.2 BACKGROUND

DOD planning for the logistics support to sustain major contingency operations, including amphibious assault operations and Logistics-Over-The-Shore (LOTS) evolutions, relies extensively on the utilization of U.S. Flag commercial shipping. Since the mid-1960s commercial shipping has been steadily shifting towards containerships, Roll-On/Roll-Off (RO/RO) ships, and bargeships (e.g., LASH, SEABEE). By 1985 as much as 85% of U.S. Flag sealift capacity may be in container-capable ships – mainly non-self-sustaining (NSS) containerships. Such ships cannot operate without extensive port facilities.

Amphibious assault and/or LOTS operations are usually conducted over undeveloped beaches, and expeditious response times preclude conventional port development. The handling of containers in this environment presents a serious problem. This problem is addressed in the overall DOD Over-the-Shore Discharge of Cargo (OSDOC) efforts, which involve developments by the Army, Navy, and Marine Corps. Guiding policy is documented in the "DOD Project Master Plan for Surface Container Supported Distribution System" and the OASD I&L System definition paper "Over-the-Shore Discharge of Cargo (OSDOC) System."

In response to the DOD Master Plan, Navy Operational Requirement (OR-YSL03) has been prepared for an integrated Container Off-Loading and Transfer System (COTS) for discharging container-capable ships in the absence of port facilities. The COTS Navy Development Concept (NDCP) No. YSL03 was promulgated July 1975, and the Navy Material Command was tasked with development. The Naval Facilities Engineering Command has been assigned Principal Development Activity (PDA) with the Naval Sea Systems Command assisting.*

The COTS advanced development program includes the ship unloading subsystem, the ship-to-shore subsystem, and common system elements. The ship unloading subsystem includes: (a) the development of Temporary Container Discharge Facilities (TCDF) employing merchant ships and/or barges with add-on cranes and support equipment to off-load non-self-sustaining containerships alongside; (b) the development of Crane on Deck (COD) techniques and equipment for direct placement of cranes on the decks of NSS containerships to render them self-sustaining in an expedient manner; (c) the development of equipment and techniques to off-load RO/RO ships offshore; and (d) the development of interface equipment and techniques to enable ship discharge by helicopters (either existing or projected in other development programs).

The ship-to-shore subsystem includes the development of elevated causeways to allow cargo handling over the surfline and development of self-propelled

*NAVFAC Program Plan for Container Off-Loading and Transfer System (COTS) of Apr 1977.

causeways to transport cargo from ships to the shoreside interface.

The commonality subsystem includes: (a) the development of wave-attenuating Tethered Float Breakwaters (TFB) to provide protection to COTS operating elements; (b) the development of special cranes and/or crane systems to compensate for container motion experienced during afloat handling; (c) the development of transportability interface items to enable transport of essential outsized COTS equipment on merchant ships – particularly bargeships; and (d) the development of system integration components, such as moorings, fendering, communications, and services.

The Civil Engineering Laboratory (CEL), Port Hueneme, California, was designated by the Naval Facilities Engineering Command (NAVFAC) as the responsible laboratory for the ship-to-shore subsystem. The five-volume report covers only that portion of the ship-to-shore subsystem related to the elevated causeway components and associated container-handling operations.

1.3 DEVELOPMENT PARAMETERS

The parameters used by CEL to develop and evaluate the elevated causeway system are:

Configuration Objectives

- Components are to be transportable by LST and commercial carriers such as bargeships
- Provide for lighterage operation/cargo handling and transfer beyond the surf zone
- Capable of being installed in breakers/swells up to 7 feet (2.1 m); survive in swells up to 15 feet (4.6 m)
- Capable of being installed at an average rate of 2 to 4 hours per section
- Capable of being elevated 15 feet (4.6 m) above mean low water [allow for 8-foot (2.4-m) tide and 7-foot (2.1-m) swell] in water depths up to 20 feet (6.1 m) at the pierhead
- Provide fender system for pier/lighterage interface and line-handling capability for lighterage
- Provide system capability for truck turnaround on the causeway and a means for expanding the elevated causeway installations

Performance Goals

- Install elevated causeway pier from beach to point offshore suitable for lighterage operations,
  - Causeway/container crane operations: handle 20-foot (6.1 m), 22-ton (20-Mg) containers up to and including 40-foot (12.2-m) 35-ton (31.8-Mg) containers at a 40-foot (12.2-m) radius
  - Container transfer rate: handle 10 to 12 containers per hour from lighterage to shore; use multiple components to meet greater demands
- Use existing Navy assets augmented by commercial hardware to the maximum extent practical
- Be compatible with cargo from existing containerships and other container-capable ships, such as RO/RO ships, bargeships, and other cargo ships
- Provide limited container-handling capability (Lo/Ro and Ro/Ro at an early time frame)
- Introduce elevated causeway components into Fleet by end of FY 78

Operational Criteria

- Sustain operations in sea state 3 – significant wave height, 5 feet (1.5 m) – with 30-knot (15.4-m/s) winds, 4-knot (2.1-m/s) current
- Have a 20-foot (6.1-m) water depth at the pierhead
- Operate in a 7-foot (2.1-m) surf and an 8-foot (2.4-m) tide
- Survive in sea state 6 – 12-to-20-foot (3.6-to-6.1-m) waves – with 75-knot (38.6-m/s) winds, 4-knot (2.1-m/s) currents
- Survive hurricane forces when given 24-hour warning, and be operational within 48 hours following the storm

1.4 APPROACH

CEL planned the elevated causeway tests in two phases. The first phase of tests, which were conducted by CEL at Point Mugu, California, was designed [1] to investigate operational and structural capabilities of the NL elevated causeway and to develop operational procedures. No container-handling tests were included in this phase. The Phase I tests [2,3] were conducted from 16 June to 16 July 1975.

The Phase II tests were designed to be conducted by military operators, i.e., PHIBCB-ONE and ACU-ONE, Coronado, California, to determine operational limitations and any further development requirements. A survey of the landing site showed a beach gradient of about 1:30 and a water depth at zero tide of 20 feet (6.1 m) at a distance of 600 feet (182.9 m) offshore. The pier was elevated by PHIBCB-ONE on Silver Strand Beach, Green Beach Two at coordinates 32°39'08" latitude, 117°09'25" longitude, beginning 12 November 1975 and finishing on 26 November 1975. The container-handling crane was positioned on the pierhead on 1 December, with the container-handling operations beginning on 2 December and completing on 5 December 1975. The pier was left elevated until 5 January 1976 to check for pile settlement and to provide an opportunity for the pier to encounter rough seas; it was then disassembled from 5 January to 10 January 1976. Movies [3, 4] have been prepared that cover both Phase I and Phase II tests.

1.5 REPORT COVERAGE

The final documentation, which covers results of both Phase I and Phase II tests, consists of a summary report (Volume I)* and four separate technical volumes. The four technical volumes cover the following.

1.5.1 Volume II

The lift system, lift procedures, and associated equipment are covered, i.e., pier installation and retrieval methods, pile positioning, driving and pulling techniques, site and elevated causeway surveys and survey methods, and utilization of associated lift system equipment. A human engineering study was made of both the elevated causeway system hardware and the associated operational procedures. This analysis was conducted by the Human Factors Technical Division, NELC, San Diego, and CEL.

1.5.2 Volume III

The pontoon equipment (including section assembly and internal and external spudwells), structural reinforcements required for the container-handling crane, side connectors, and results of the structural behavior tests are described.

1.5.3 Volume IV

A description of the fender system, installation procedures, and lighterage impact tests is given. Also, the lighterage motions recorded during the container-handling operation are shown.

1.5.4 Volume V

The container-handling portion of the program is detailed, i.e., container transfer rates, container crane, containers, lighters, Marine Corps truck/trailers, pontoon deck reinforcement, turntable, beach ramp and matting, and air bearing transporter. An alternate method of ship-to-shore container transfer, i.e., the load-on/roll-off causeway ferry system (Lo/Ro), that uses a commercial top-lift loader was tested and is described.

*Environmental data recorded during the test period are included in Volume I.

SECTION 2

ELEVATED CAUSEWAY SYSTEM

2.1 SYSTEM DESIGN

The elevated causeway system design provides for an interface between lighterage and the shore by bridging the surf zone. The elevated access terminates at the offshore end in a pierhead that supports cargo-unloading functions. The major developments include an elevating capability for the existing NL pontoon causeway, a crane installation at the pierhead for off-loading from lighterage moored alongside the causeway, fendering to interface the elevated pierhead and the lighters, turnaround components to handle truck/trailers on the causeway, and a two-way traffic access from the pierhead to the beach.

The system is based on the 3x15 pontoon section 21 feet (6.4 m) wide by 90 feet (27.4 m) long, which is elemental to the Amphibious Construction Battalions. To convert the floating 3x15 structure to the elevating mode requires the addition of spudwells, either external or internal. The internal spudwells are used in the pierhead where sections are side by side, and the external ones are used in the connecting causeway.

Basically, the sequence of installation is:

(1) Beach all sections connected in the floating mode

(2) Place and drive piling

(3) Install the lift jacks

(4) Break the end-to-end (or side-by-side) connection on the section to be elevated

(5) Elevate the section

(6) Remake the connections when adjacent sections are elevated

(7) Secure the elevated section to the piles (temporary)

(8) Remove the jacks

(9) Move on to the next section and repeat steps 3 through 8

(10) Secure the elevated section to the piles (permanent)

(11) Install fender components after pierhead is complete

After the work is underway, many of the functions are performed concurrently.

The modularity of the elevated system allows the field commander flexibility in sizing out the pierhead and approach. As a minimum, the four special pierhead sections should be used to establish the off-shore container-handling facility. The 2x2 section pierhead can be expanded in both length and width dimensions to meet requirements. The length of the approach causeways should be selected to bridge the surf and locate the pierhead in sufficient water depth for anticipated lighterage operations.

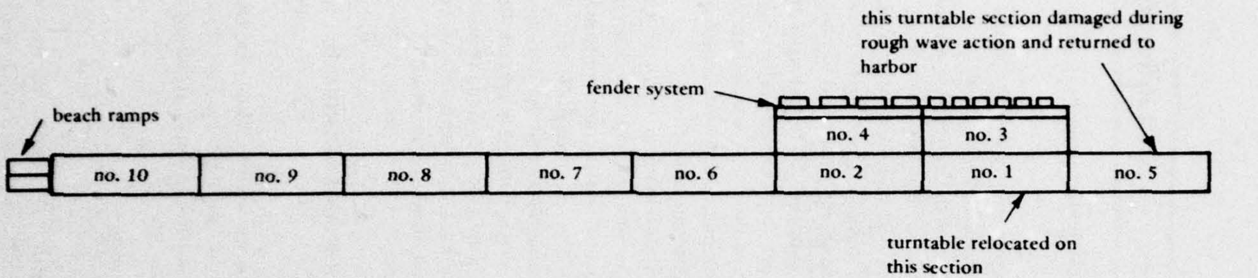
The advanced development tests at Coronado, California, were conducted with the structure illustrated in Figure 1. The structure consisted of four pierhead sections (No. 1 through 4), five approach sections (No. 6 through 10), and the turntable section (No. 5) located seaward of the pierhead. Before the turntable section could be elevated, it was damaged and could not be used. Consequently, the turntable was relocated to pierhead Section No. 1.

2.2 INSTALLATION AND RETRIEVAL EQUIPMENT

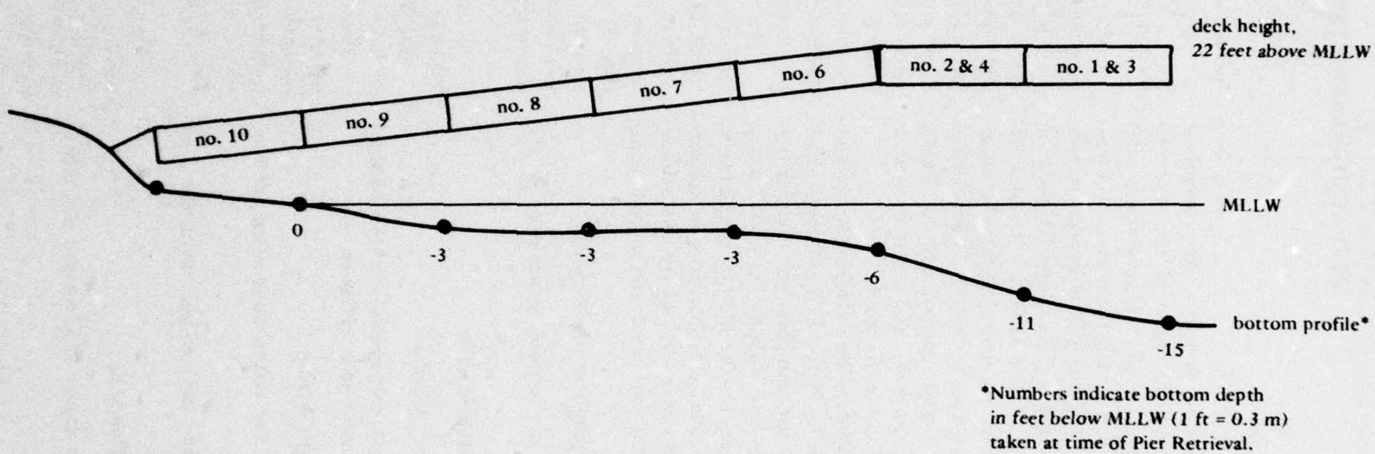
The hardware associated with installation and retrieval consists of (a) a lift system, (b) lift components integral with the basic structure, and (c) support equipment.

2.2.1 Lift System

The lift system [5] consists of five hydraulic chain jacks (includes one spare jack), gimbals, 320 feet (97.5 m) of 1-1/4-inch (31.8-mm) stud link chain, a hydraulic power unit, 300 feet (91.4 m) of hydraulic hose, and miscellaneous hardware. An



(a) Section location.



(b) Pier elevation and bottom profile.

Figure 1. Elevated causeway at Coronado.

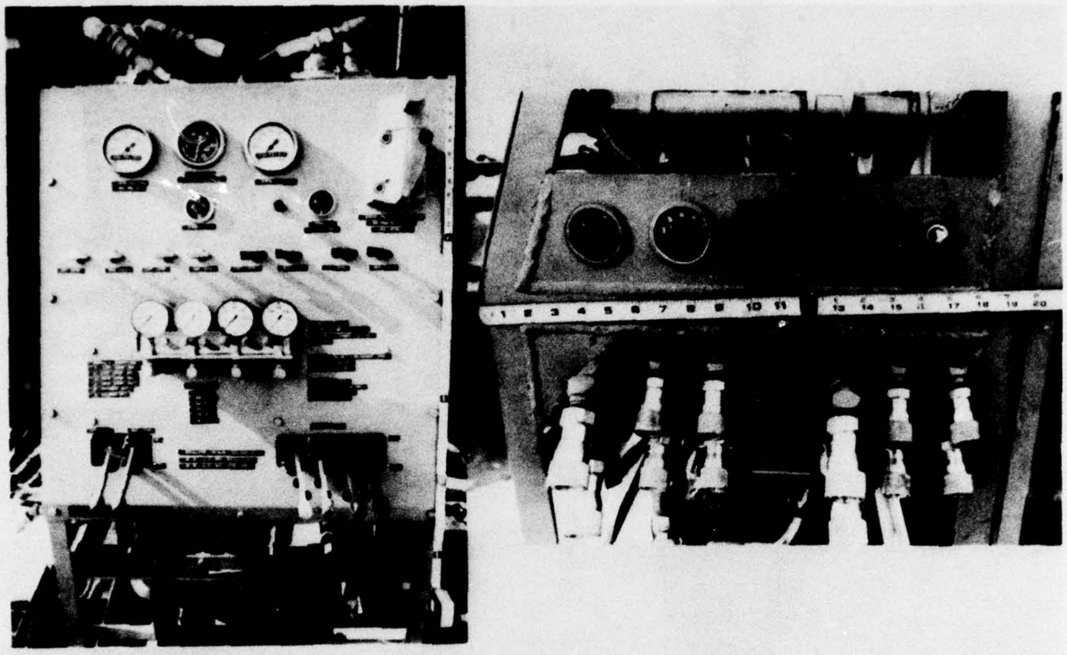


Figure 2. Hydraulic chain/jack power supply and control system.

8 x 8 x 20-foot (2.4 x 2.4 x 6.1-m) container has been adapted to house the complete system. The container and lift system weigh 30,000 pounds (13.6 Mg). Tiedown adapters and rigging hardware have been fabricated to secure the equipment inside the container for shipment.

Four hydraulically actuated chain jack assemblies connected to a power supply/control unit with quick-disconnect flexible hose (Figure 2) are employed to raise or lower an NL causeway section to a prescribed height. These four jacks, which are positioned on steel pilings driven through spudwells at the corners of the NL section, are capable of being actuated in unison or individually by a single operator. Each jack (Figure 3) has a lifting capacity of 50 tons (45.3 Mg), with a total system lift capacity of 200 tons (181.4 Mg) available under optimum load-sharing conditions. Each jack is a double-acting hydraulic ram that uses a maximum system pressure of 2,500 psi (17.2 MPa) with a stroke of 12-1/2 inches (317.5 mm). The ram is extended and retracted, which alternately pulls and holds 1-1/4-inch (31.8-mm) stud link chains with lift and hold latch assemblies. The load is alternately transferred between the lift latch assemblies and the hold latch assemblies that are operated hydraulically. The NL section can be raised at a rate of 30 feet (9.1 m) an hour by utilizing the power supply that is part of the system.

The hydraulic power unit that controls the jack system consists of a 28-hp (20.9-kW), four-cylinder Perkins diesel engine driving a PV-B10 Vicker variable-displacement pump having the following characteristics:

1,800 rpm . . . 10 gpm (0.631 mm^3/s) at 1,500 psi (10.34 MPa); 10 hp (7.5 kW) input

3,200 rpm (max) . . . 18.6 gpm (1.17 mm^3/s) at 3,000 psi (20.68 MPa); 36 hp (26.85 kW) input

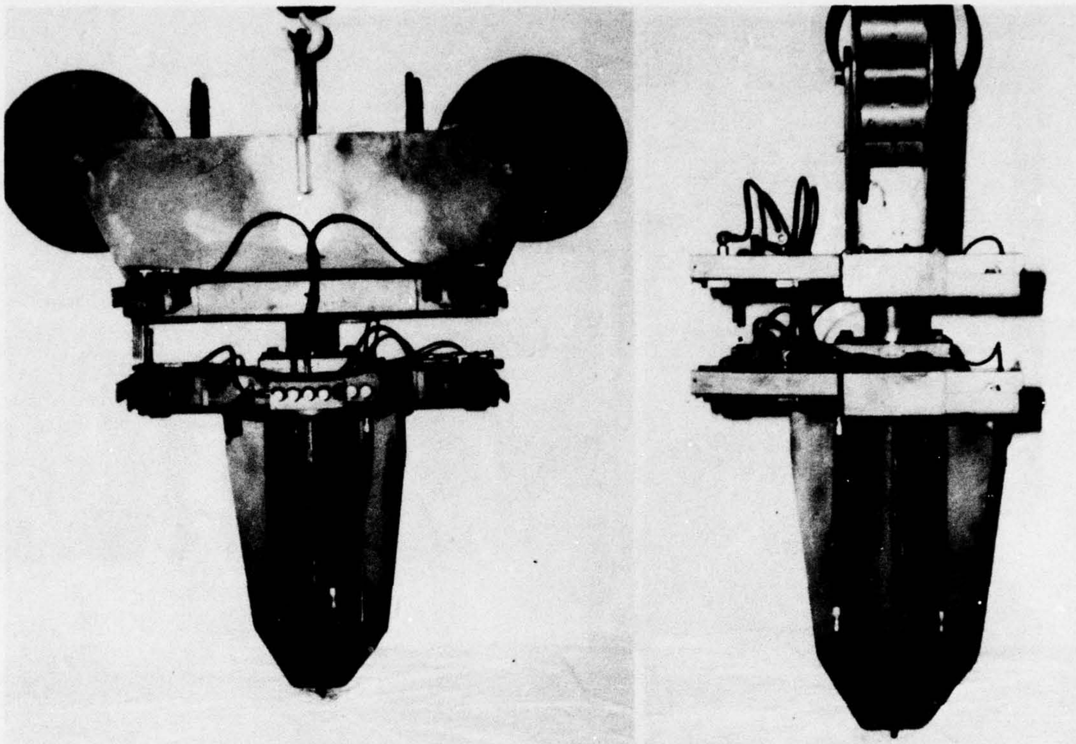


Figure 3. Hydraulic chain jack, 50-ton capacity.

2,200 rpm (max) . . . without supercharge	12.36 gpm (0.78 mm^3/s) at 2,500 psi (17.23 MPa); 20.5 hp (15.3 kW) input

The available continuous brake horsepower from the Perkins engine at 2,200 rpm is approximately 28 hp (21.0 kW); this satisfies the 20.5-hp (15.3-kW) demand of the Vicker PV-B10 pump at 2,200 rpm without supercharge. The four jacks are controlled by two latch levers and four lift cylinder levers in conjunction with eight latch lockout valves. The system pressure and latch pressures are adjustable for optimum operation. Also, the system pressure, latch pressure, and individual lift cylinder pressures are monitored for system control.

The structural characteristics of the chain jacks require the load to be equally shared on each side of the lift cylinder. This requirement is met through a gimbal assembly (Figure 4). The steel gimbals weigh approximately 350 pounds (158.8 kg) each and can be manually positioned (four pieces).

2.2.2 Causeway Section Lift Components

To convert the standard floating 3x15 NL pontoon structure to a structure that can be elevated requires the addition of external or internal spudwells.*

Four 3x15 pontoon sections were assembled at CEL with internal spudwells for the pierhead. The internal spudwells used in these sections provide for a clear outside edge that permits sections to be positioned side by side. Four internal spudwells were assembled in two of the sections; the other two sections had six internal spudwells assembled in order to support the container-handling crane.

Six existing 3x15 NL pontoon sections, which were obtained from Amphibious Construction Battalion-ONE (PHIBCB-ONE), Coronado, were modified by adding AP7 mounting plates for external spudwells. These AP7 plates were installed by the Public Works Center (PWC), U.S. Naval Base, San Diego, California. After the sections were modified,

*The spudwells are described in detail in Volume III.

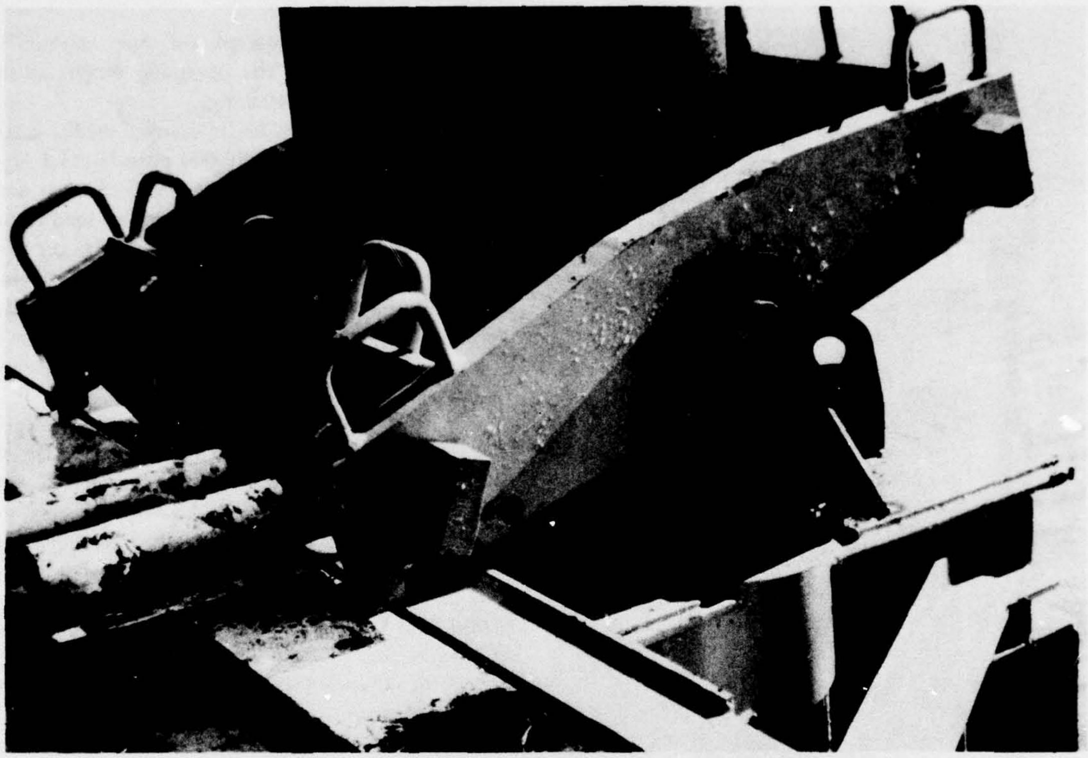


Figure 4. Gimbal assembly mounted on external spudwell.

PWC, San Diego installed the external spudwells and load-tested each section statically with 85-ton (77.1-Mg) weights.

The spudwells incorporate padeyes for lifting, a motion compensation system for dampening dynamic loads when lifting the section from the surf, and padeyes for temporarily securing the section to the pile for jack removal. The gimbal assemblies that equalize the load on each side of the lift jack cylinder are pinned to the lift padeyes. The lift padeyes are attached to the pontoon section through the motion compensation system.

The motion compensation system consists of a 50-inch (1.27-m) long modified cylindrical rubber piston housed inside an 8-inch (203.2-mm) steel tube. The rubber is compressed in the steel tube by forces applied through the lift padeyes and a rod and washer assembly. The rubber compensator has a spring constant of approximately 28,000 lb/in. (500.1 kg/mm) deflection when housed in an 8-inch (203.2-mm) steel tubing after initial confinement. An initial spring constant of approximately 1,250 lb/in. (22.3 kg/mm) is applicable to this system during the initial 8-inch (203.2-mm) compression of the rubber within the housing.

Padeyes for temporarily securing the section to the pile caps are rigidly attached to each spudwell. During the final stages of section lifting, these padeyes are attached to the pile caps through a turnbuckle arrangement. The turnbuckles are adjusted for load equalization each side of the pile caps (Figure 5).

The pile caps function as jack/pile adapters and as a temporary causeway-to-pile connection system. The caps rest on the top of each pile, but bear on the circumference of the pile. Each cap has two padeye weldments for attaching the turnbuckles. The jacks are inserted in each pile cap during the causeway elevating process.

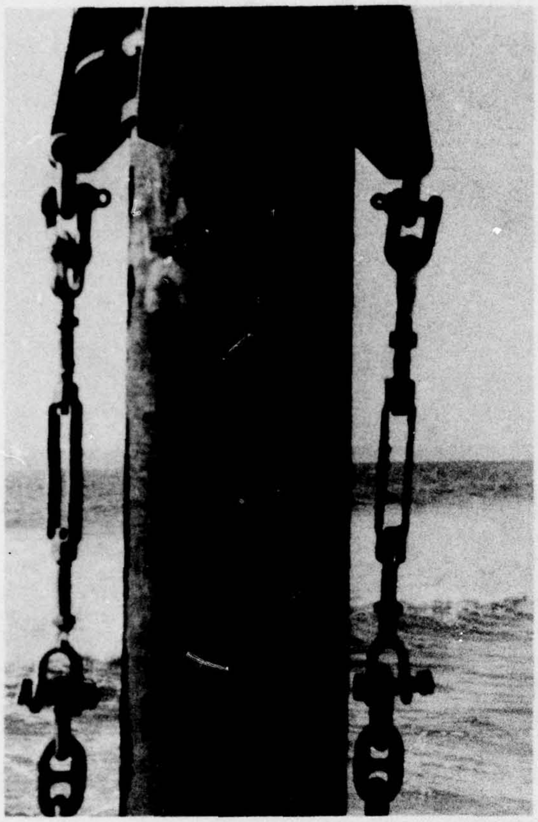


Figure 5. Pile cap and turnbuckle temporary causeway suspension system.

2.2.3 Support Equipment

A P&H Model 535, rubber-tired truck crane, weighing 104,000 pounds (47.2 Mg), was used to handle the pile hammer and piling. The crane had a rating of 35 tons (31.8 Mg) and was fitted with a 70-foot (21.3-m) long boom with standard tip. A working load versus operating radius curve for 360 degrees of rotation (outrigger fully extended and locked) and operating from a stable platform is given in Figure 6. Minimum horizontal and vertical reach with the boom as required for pier erection is included in Figure 6. The operating weight of the truck crane is 55 tons (49.9 Mg).

A BLH Model B210 hydraulic crane, 5-ton (4.5-Mg) capacity, weight 29,000 pounds (13.2 Mg), was employed on the elevated sections to assist with the transfer of jack equipment. A working load versus operating radius curve for 80% of tipping on firm ground without outriggers extended is given in Figure 7. Minimum horizontal and vertical reach with the boom as required for pier erection is included in Figure 7. The operating weight of the hydraulic crane is 12-1/2 tons (11.2 Mg).

The pile hammer used to drive the 20-inch (508-mm) diameter piles was a diesel-operated DE-30 [weight, 9,075 pounds (4.1 Mg); rated energy, 22,400 ft-lb (39.4 kJ); length, 15 feet (4.6 m)]. A special set of free hanging leads was provided to hold the hammer on top of the pile during the driving operation. A smaller hammer, a DE-20 [rated energy, 16,000 ft-lb (21.7 kJ)], had been used during some early tests, but it was considered inadequate for driving the 20-inch (508-mm) diameter piles into a firm sand bottom.

The other hardware used included pile caps, detachable links, chain shackles, stud link chain, turnbuckles, welding machines (electric), and oxy-acetylene gas cutting rigs.

2.3 CAUSEWAY INSTALLATION

During a 20-day period from 3 November 1975 to 23 November 1975, a 25-man PHIBCB-ONE causeway elevating crew erected a nine-section causeway pier system. The elevating crew had a week of familiarization with the equipment within a harbor area before commencing the pier erection. The pier construction was a continual process of familiarization and learning. In addition to hardware testing, the emphasis of the Coronado pier construction was to develop optimum man/equipment interactions. As the process of familiarization and learning progressed, operations became more concurrent. Toward the end of pier construction the most effective working teams had been organized and sufficiently trained such that a causeway section could be elevated in less than 4 hours.

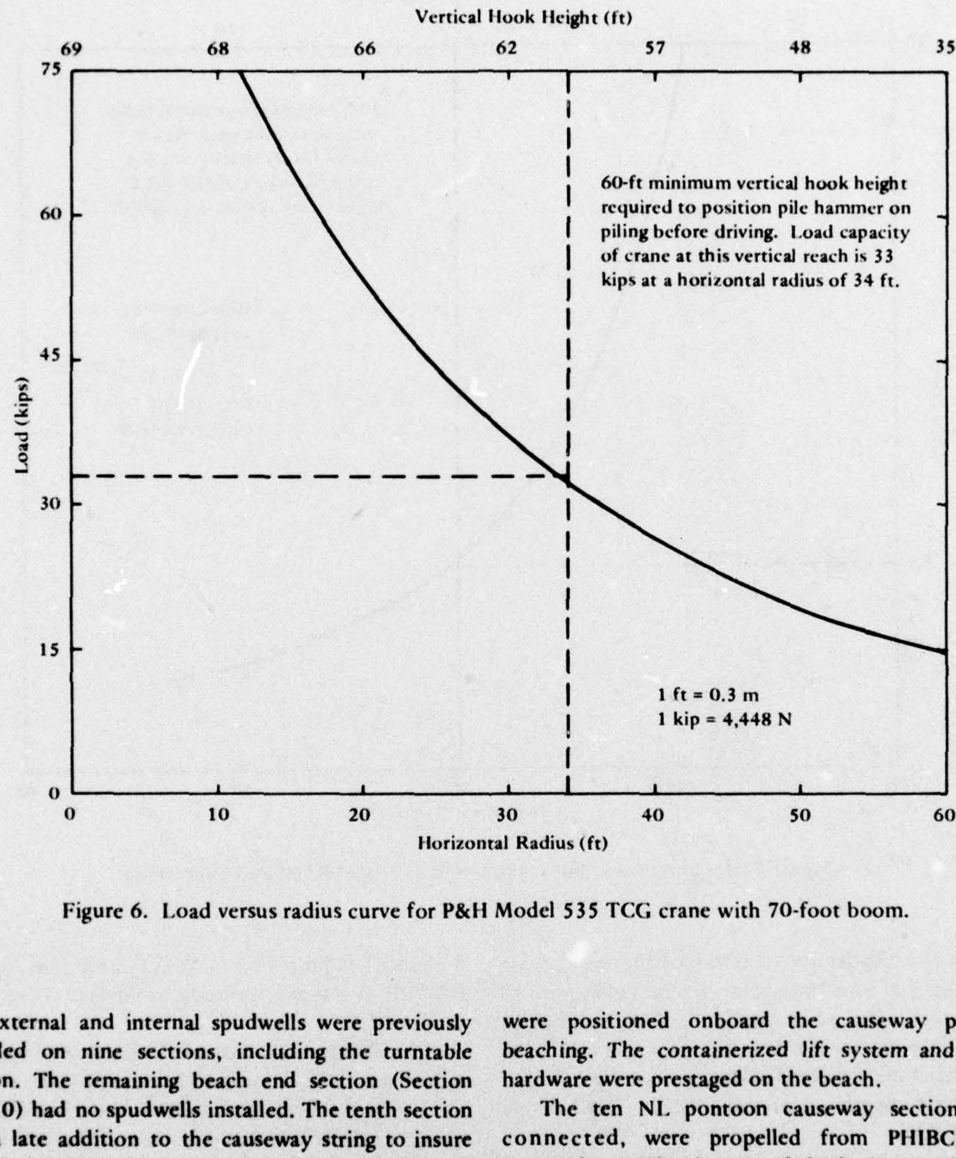


Figure 6. Load versus radius curve for P&H Model 535 TCG crane with 70-foot boom.

External and internal spudwells were previously installed on nine sections, including the turntable section. The remaining beach end section (Section No. 10) had no spudwells installed. The tenth section was a late addition to the causeway string to insure the pierhead would be positioned beyond the surf zone. The placement of the pierhead beyond the surf zone resulted in minimal relative motion between the floating lighterage and the cranes positioned on the pierhead.

A truck crane, a hydraulic crane, steel pipe piling [20-inch (508-mm) diameter, 1/2-inch (13-mm) and 3/8-inch (9.5-mm) wall thickness], a DE-30 diesel pile hammer, beach ramps, and a turntable assembly were positioned onboard the causeway prior to beaching. The containerized lift system and rigging hardware were prestaged on the beach.

The ten NL pontoon causeway sections, end-connected, were propelled from PHIBCB-ONE, Coronado, California, out of the harbor to the open sea using two PHIBCB-ONE warping tugs (Figure 8). The sections were momentum-beached at 0915 on 12 November 1975, and two TD-25 crawler tractors secured the beach end of the causeway. Six piles at the seaward end of the floating causeway were dropped and driven approximately 6 feet (1.8 m) each.

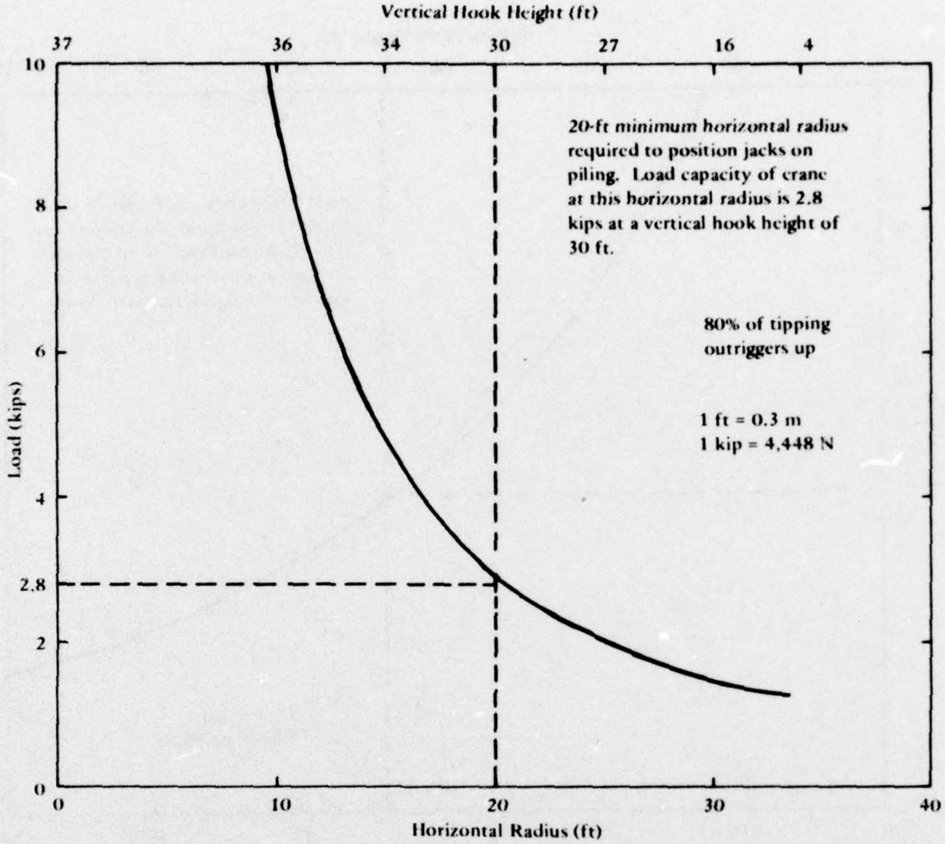


Figure 7. Load versus radius curve for BLH Model B210 hydraulic crane.

The pile lengths were determined for this exercise on the basis of soundings taken several weeks prior to the exercise. The piles were spliced to the various lengths required for the different positions within the constructed pier. A detailed description of pile length and water depth determinations is included in Appendix A.

A two-piece, 30-foot (9.1-m) long steel ramp provided a roadway from the elevated shore section to the beach over which support equipment could be transferred. Each ramp half, which weighs 9 tons (8.2 Mg), was attached to the open padeyes of the NL pontoon end connection. These ramps were installed using the truck crane (Figure 9). The ramp is capable of supporting the 140,000-pound (63.5-Mg) container-handling crane. M8A1 steel matting was provided as a beach surfacing at the end of the beach ramp.

The elevating procedure consisted of lifting each section separately, beginning from the beach end with Section No. 10. This required disconnecting the section to be elevated from a floating section before elevating it, and then connecting it to an elevated section after lifting. The five approach sections leading from the beach were sloped at 2-1/2 feet (0.8 m) per section, and the remaining sections were set level to form the pierhead (Figure 1).

The truck crane was placed on the floating sections to position and drive the piles and to position jack equipment on the driven piles (Figure

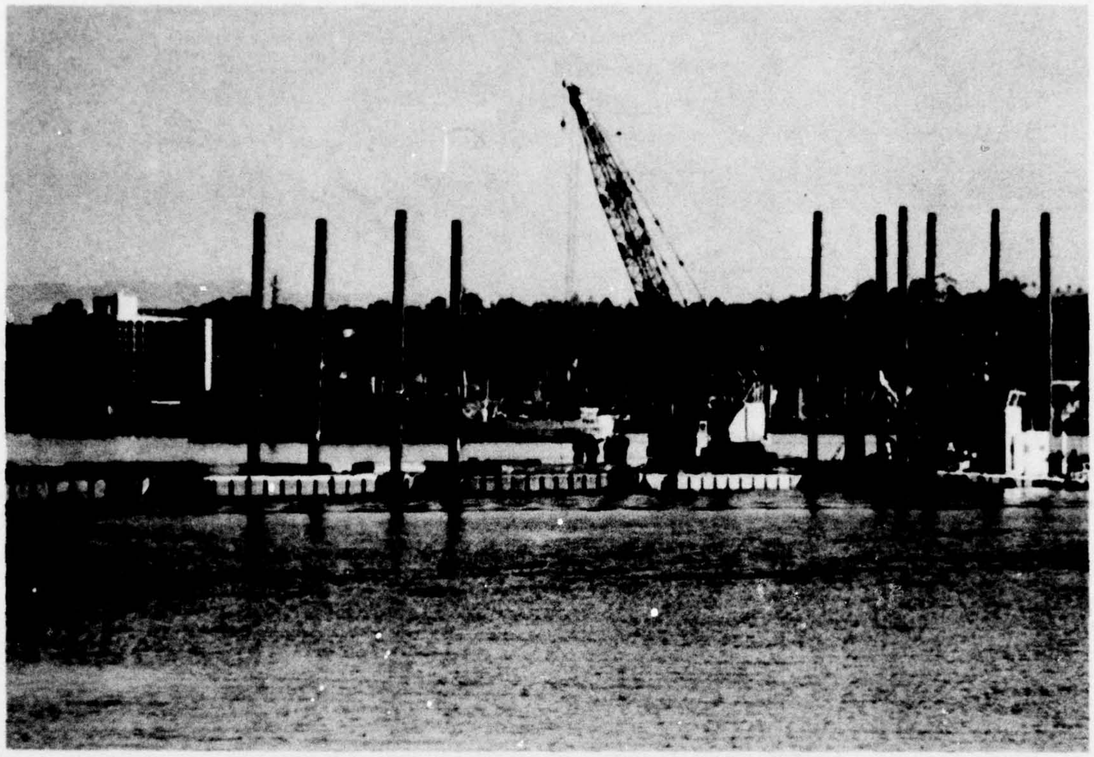


Figure 8. Transport of causeway to test site.

10). It was also used to pull the piles during retrieval. The truck crane operations are summarized in Table 1.

The hydraulic crane was located on the elevated sections to remove the jacking equipment after each section was elevated and to transfer the power control console and jacks to within the reach of the truck crane (Figure 11). A rough terrain forklift was utilized on the elevated sections to assist in transporting rigging hardware, pile caps, and welding equipment. It was also used to transfer piles to the beach after they had been pulled during retrieval.

Two TD-25 dozers with 100,000-pound (45.4-Mg) capacity winches were utilized on the elevated sections to assist in reconnecting the elevated sections (Figure 12). These dozers also assisted in beaching the causeway and were used to maintain the sand ramp and roadway to the pier.

The pierhead was constructed by elevating Sections No. 2, 1, 4, and 3 in that order. The truck crane and DE-30 pile hammer were elevated on Section No. 1. The truck crane was used to transfer the jacks from Sections No. 1 and 2 to Sections No. 4 and 3. As each section was elevated, a temporary turnbuckle connection between the section and pile was made. This connection was backed up by a permanent welded gusset connection* between pile and spudwell as pier construction proceeded. After elevation, the side connectors* were installed. The nine-section pier was constructed in 9 days. Detailed description, analysis, and recommendations for construction activities and hardware are included in Appendix B.

*The connection is described in detail in Volume III.

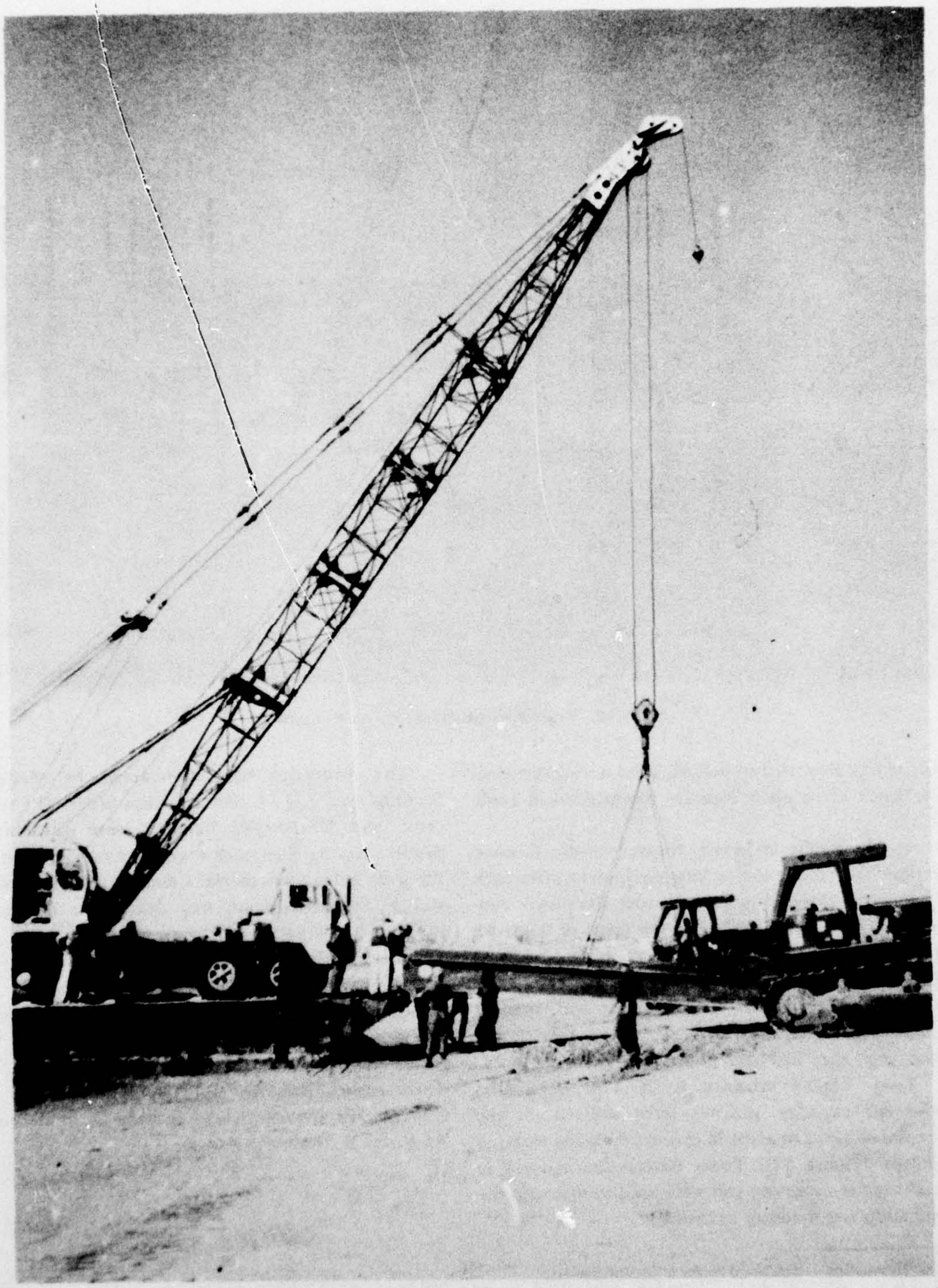


Figure 9. Truck crane positioning beach ramps prior to pier construction.

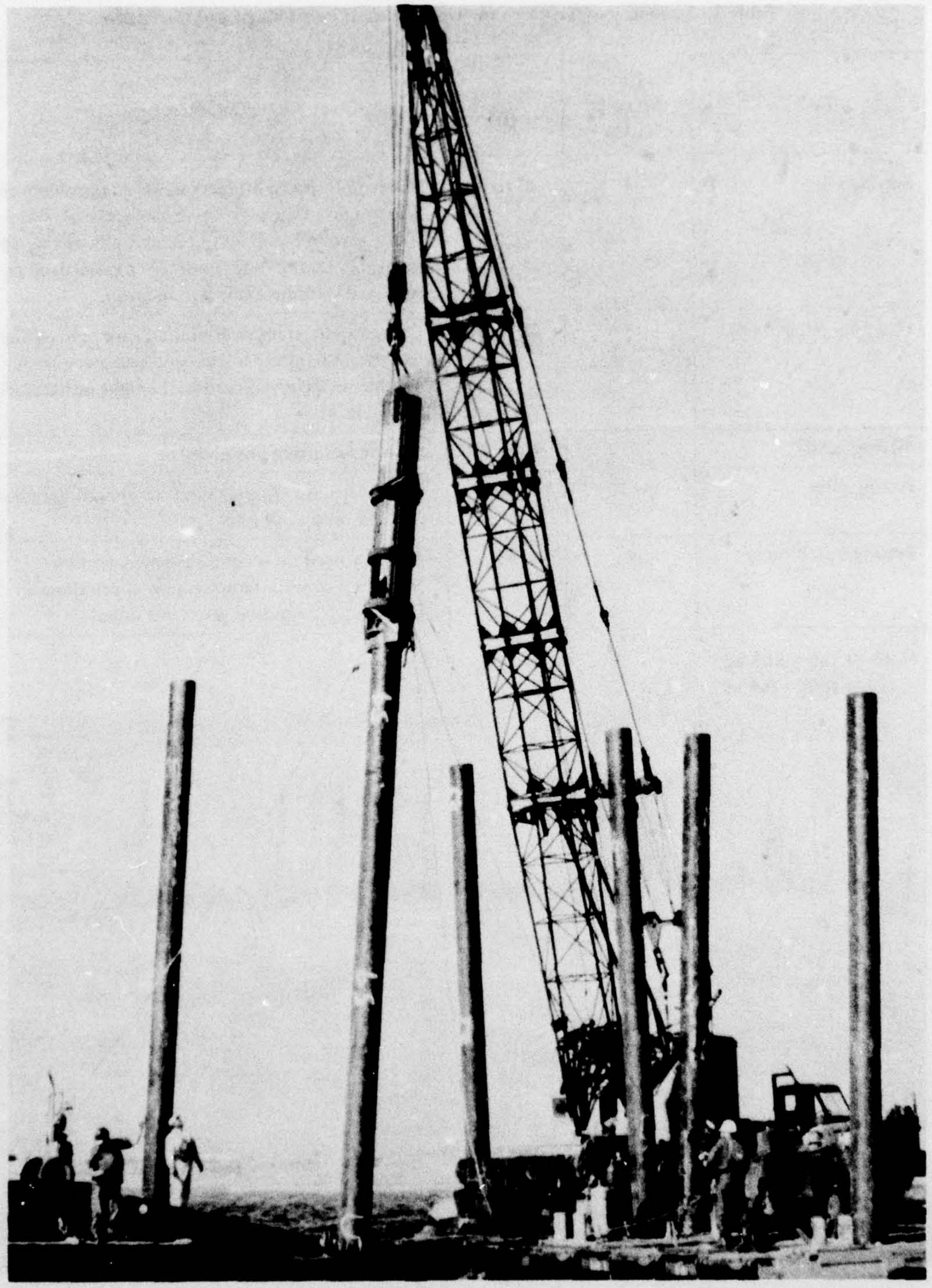


Figure 10. Driving steel pipe pile with DE-30 diesel hammer and truck crane.

Table 1. Summary of Truck Crane Operations at Point Mugu and Coronado

Task	Maximum Weight (ton)	Radius (ft)	Comments
Setting piles	3	20 to 30	Pile length (up to 60 feet) more of a problem than pile weight. Causeway motion necessitated extreme care in handling to prevent pile hitting and damaging boom. Pile tip dragged along deck to spudwell to reduce pile pendulation.
Handling pile hammer	5	20 to 30	Causeway motions necessitated care in handling to prevent hammer hitting and damaging boom. Tagline ineffective because of height of hammer above deck.
Placing jacks	1-1/2	20 to 30	No unusual problems noted.
Pulling piles	to 30	15 to 25	Crane capacity (tipping load) at operating radius reached on several piles.
Setting beach ramp	9	35	Ramp stowed on second causeway section. Necessary to walk ramp section approximately 180 feet. No unusual problems noted.

Note: 1 ton = 907 kg
1 foot = 0.3 m

Figure 11. Transferring chain jacks with hydraulic crane during pier construction.

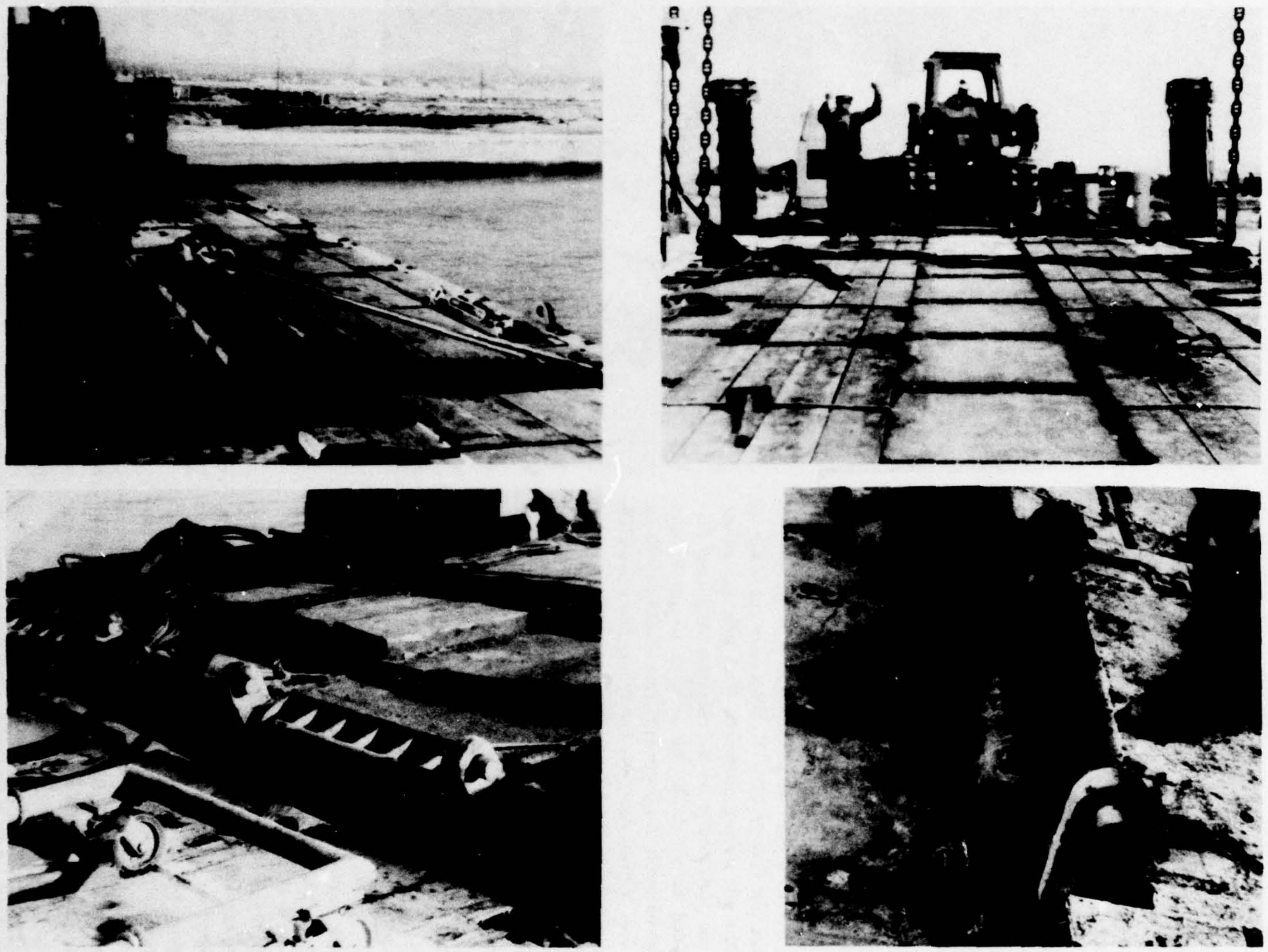


Figure 12. End-connecting causeway sections with TD-25 dozer after elevating.

2.4 CAUSEWAY RETRIEVAL

Retrieval of the elevated causeway began on 5 January and was completed on 10 January. The personnel from PHIBCB-ONE who erected the pier were maintained in identical teams for the retrieval. Pier retrieval activities are discussed and analyzed in detail in Appendix B.

The first steps in retrieval were the removal of the fender system* and the lowering of side-connected pierhead** Sections No. 3 and 4. The piles for the fenders had been driven deeper than the other pier support piles and, thus, required the maximum force when pulled. One fender pile was driven 21 feet (6.4 m) into the silty, sand bottom. The pull required to remove this pile was estimated at 15 to 20 tons (13.7 to 18.1 Mg).

The piles were pulled with the truck crane by wrapping a chain around the pile; the chain was held in place by a pin that was inserted through holes cut in the pile (Figure 13). The holes were cut just prior to the pile pulling operation. Each pile was pulled, placed horizontally on the causeway deck, and then skidded to the beach by a rough terrain forklift. Approximately 2-1/2 hours were required to pull the six fender piles. After the last fender pile was pulled, a warping tug towed the fender system to the harbor [6].

All the pier support piles in the causeway had been welded to the pontoon sections by means of gusset plates. These plates were easily and quickly cut by a oxy-acetylene burning crew operating in advance of the jack crews (lowering process). This left the sections supported by the pile cap/turnbuckle temporary support system.

Figure 13. Pulling fender pile with truck crane during pier retrieval.

The two midsection support piles of Section No. 4 were pulled, and then four jacks were installed on diagonal support piles in the corners of Sections No. 3 and 4. While the jacks and gimbal assemblies were being installed, the side connectors between sections were released and pulled back into Sections No. 1 and 2. Sections No. 3 and 4 were lowered end-connected (Figure 14) with two jacks set diagonally on each section. Upon being released, the jacks were transferred to the piles of Section No. 6 using the truck crane located on Sections No. 1 and 2. The crane then pulled the piles from Sections No. 3 and 4. The outside piles were pinned and loosened utilizing wave action in the method described in Appendix B. Removal of the eight piles of Sections No. 3 and 4 took about 2-1/2 hours, after which Sections No. 3 and 4 were towed to the harbor.

Sections No. 6 through 10 were lowered while end-connected (Figure 14). Sections No. 1 and 2 remained elevated at the pierhead. The hydraulic crane remained on Sections No. 1 and 2 to place the jacks for the lowering of these sections.

*Description and use of the fender system are presented in Volume IV.
**Description and use of the side connectors are presented in Volume III.

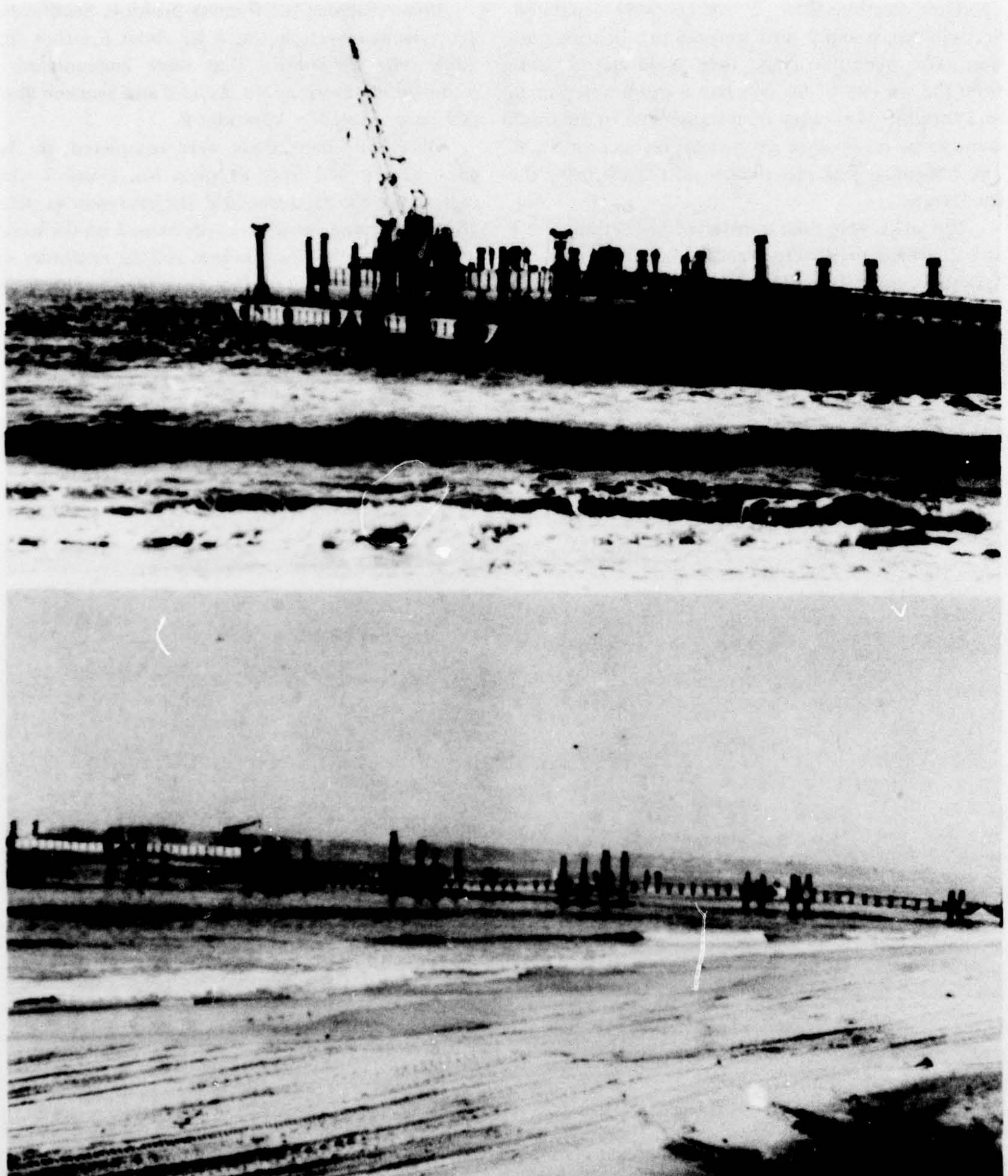


Figure 14. Causeway section lowering during pier retrieval.

Top: lowering two pierhead sections simultaneously.
Bottom: lowering several end-connected roadway sections simultaneously.

After Sections No. 2 and 6 were separated, Sections No. 6 and 7 were lowered to a floating position. The hydraulic crane then removed the jacks from the sea end of Section No. 6 and lowered them to a forklift. They were then transferred to the truck crane to be set in place on the piles on Section No. 8. The remaining jack movements were made using the truck crane.

The jacks were then transferred to Sections No. 1 and 2, where they were placed on the piles by the hydraulic crane (see Figure 15). While the sections were being lowered, the truck crane began pulling the piles from the five roadway sections that were already floating (Figure 15).

Upon reaching the floating position, Section No. 2 overlapped Section No. 6 by about 6 inches (152 mm). The difficulties that were encountered in reconnecting Sections No. 2 and 6 and Sections No. 1 and 2 are covered in Appendix B.

Once the connections were completed, the last piles were pulled from Sections No. 1 and 2 while tugs and a TD-25 dozer held the causeway in place. The truck crane, which was positioned on the beach, then removed the beach ramps, and the causeway was pushed from the beach by two TD-25 dozers and towed to the harbor by two warping tugs.

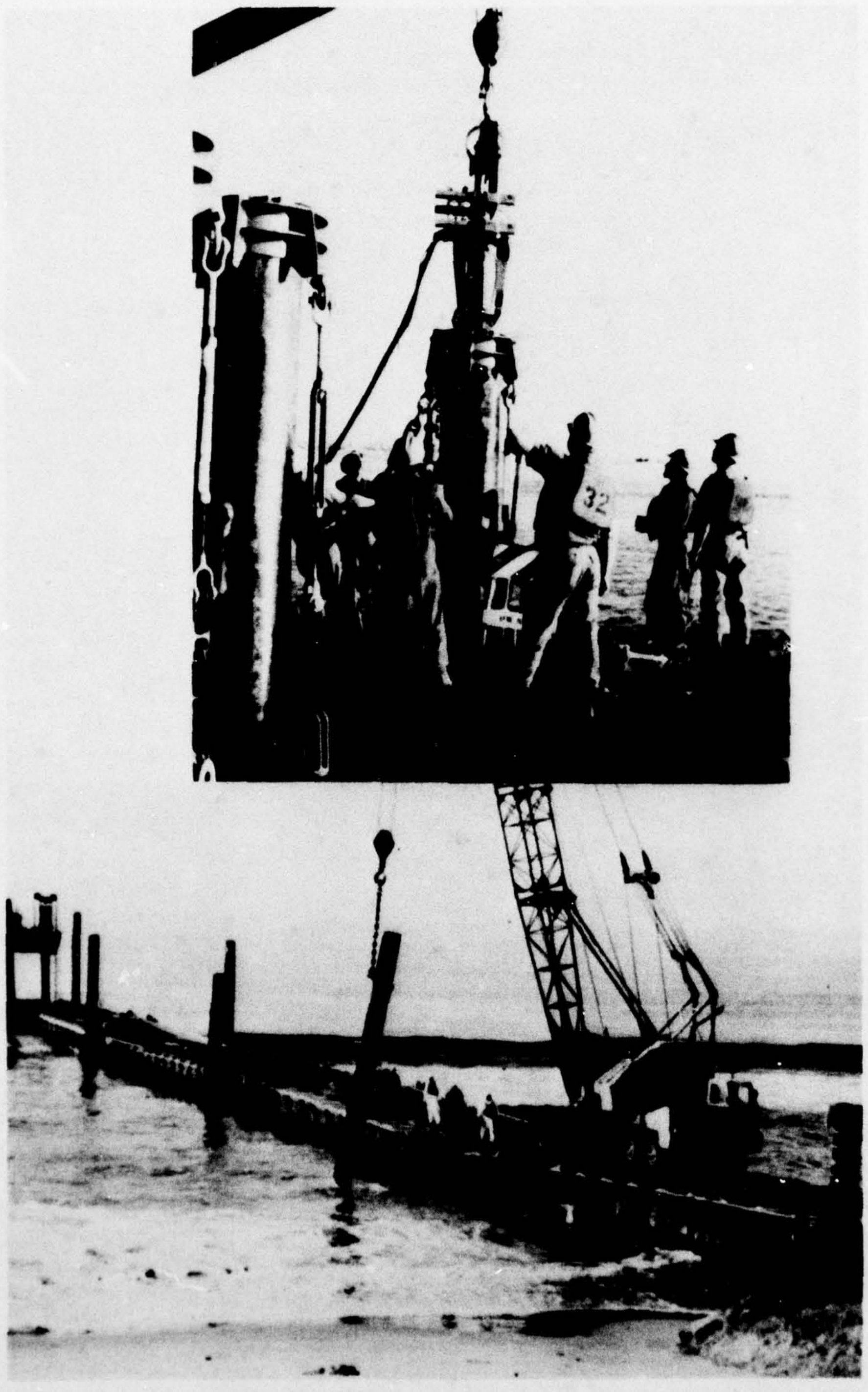


Figure 15. Top: hydraulic crane placing jack on pile in preparation of lowering pierhead. Bottom: truck crane pulling pile from floating sections after lowering.

SECTION 3

TEST RESULTS AND ANALYSIS

The complete test results, analysis, conclusions, recommendations, and personnel requirements for all pier construction hardware components and construction methods are included in Appendix B. The more significant test results are summarized here.

3.1 MAJOR HARDWARE

Two major hardware components, the section spudwells and the lift system comprising the causeway section elevating system, were analyzed.

3.1.1 Spudwells

The internal and external spudwells with the compensator systems performed well during the operation. The 23-inch (584.2-mm) diameter spudwell hole provides sufficient clearance for the 20-inch (508-mm) OD pile even when the roadway-to-pierhead sections are tilted as much as 2-1/2 feet (0.8 m) per 90 feet (27.4 m) upward from the beach.

Four external spudwells were installed on the beached section during the exercise. The external spudwell connection consists of eight A6 bolts inserted through the AP7 plates and 6 x 6 x 1/2-inch (15 x 15 x 1.2-cm) angles of the causeway sections. This connection proved to be effective for the dead and live loads occurring during this exercise.

The external spudwells require special installation methods because the bolted connection precludes spudwell installation at sea without diver support. A connection that incorporates a guillotine arrangement is under development to replace the eight A6 bolts. With the guillotine connection, the external spudwells could be installed at sea using a small crane and three riggers after side-launching the causeway sections.

3.1.2 Lift System

The lift system, which consists of four jacks and a power unit/control console, performed well during both pier construction and retrieval. Lift rates of 1/2 foot (0.15 m) per minute were achieved with this system. Complete descriptions and analysis of a lift-system installation and operation are covered in Appendix B.

3.2 MINOR HARDWARE

The minor hardware equipment investigated consisted of the temporary suspension hardware, gimbal assemblies, causeway section connection after elevation hardware, and pile guides. The minor hardware, except the pile guides, is described and discussed in Appendix B.

Pile guides were used to align the pile in the fender external spudwells only during positioning and driving (Figure 16). The guides were manually installed by four men. Without pile guides the pile could be tilted 3 inches (76.2 mm) in 60 inches (1.5 m). This misalignment is reduced to 1/2 inch (12.7 mm) in 60 inches (1.5 m) with the use of the pile guides. The pile guides were not used during pier erection because maximum pile/spudwell clearances were required to allow the pile to be tilted seaward to facilitate causeway connection after elevation as discussed in Appendix B. Also, maximum pile/spudwell clearances were needed so that the sections could be tilted during the final stages of section elevation to obtain the required roadway grade. Removable pile guides may be desirable if it is determined that piles should be driven vertically; this would significantly reduce pile binding and locked-in horizontal loads between spudwells and piling after the sections are elevated. Removing the guides after pile positioning/driving, but before elevating, would allow the sections to be easily connected and tilted.

3.3 TEST CRITIQUE

A critique of the tests was held on 4 December 1975 at the Coronado test site, and comments and suggested system/operation improvements were

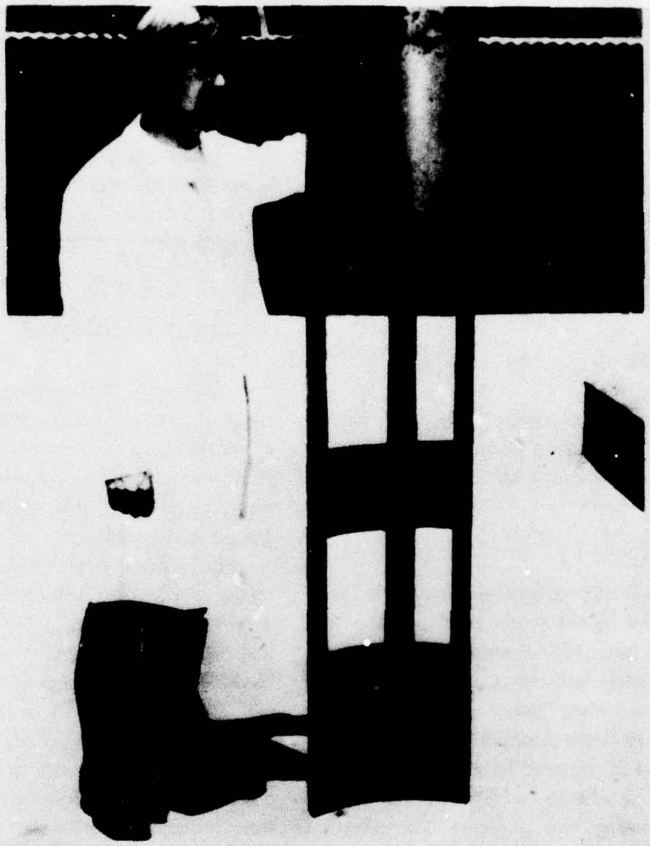


Figure 16. Pile guides used in the fender external spudwells.

presented by the military operators (PHIBCB-ONE). This was followed by a meeting at CEL on 8-9 December 1975 with personnel from PHIBCB-TWO and PHIBCB-ONE to discuss the operation and proposed modifications. It was determined that the elevated causeway system can be used in its present form to elevate NL pontoon causeway sections over the surf zone to provide a pier for transferring 20-ton (18-Mg) containers to the beach. The elevating system should not be any more complicated than it is at present. The critique summary is as follows:

- Organize and identify all personnel for each particular job.
- Brief working people on total project sequence.
- Beach causeway at high tide.
- Check and adjust alignment of floating sections prior to dropping pile.
- Drive all piles immediately after beaching.
- Develop priority for movement of equipment onto pier during pier construction.
- Reduce number of hydraulic hoses and connections between jacks and control console.
- Improve gimbal connections and handling.
- Develop side connectors that can be easily installed.
- Develop personnel ramps for gimbal installation.
- Improve scaffolding for welding over sides.
- Optimize welding sequence.
- Develop better method for attaching pile to sections other than welding.
- Develop ladder from elevated sections to floating sections.
- Develop better way of attaching timbers to pontoon deck (tractor destroys tie bars).
- Develop a continuous roadway for truck operation across end connectors.
- Provide for communications to beach from pierhead – hard wire, radios.

Those critique statements that point out deficiencies in the system are analyzed in detail in Appendix B.

3.4 ELEVATING SEQUENCE AND PIER CONSTRUCTION OPTIONS

The elevated causeway system was constructed from the seaward end during the Phase I tests. For the Phase II tests, the construction proceeded from the shore out. It appears that a pier system, such as depicted in Figure 1, would normally be constructed from the beach toward the sea end. In this case, the end connection separation required for elevating the sections can be easily gained by moving a string of floating causeway sections seaward. Mooring isolated floating causeway sections after the first beach section has been elevated is not affected because causeway sections are pile-pinned prior to being elevated. Also, welding crews and support equipment can easily traverse the elevated sections from the beach end.

Causeways elevated from the seaward end are isolated islands during the elevating process, thereby making it difficult to utilize mobile welding equipment and support from the beach on the elevated sections. Also, the surf continually breaks over the seaward work areas for each causeway section to be elevated.

The elevated causeway system is very versatile and can be constructed in sequences configured to meet Fleet requirements, depending on environmental conditions and construction equipment availability. Table 2 summarizes these options.

3.5 MULTISECTION LIFT

During the retrieval of the pier system it was found that several sections could be lowered simultaneously while end-connected. This expedient method of pier retrieval revealed that multisection lifts could be utilized during pier construction to achieve a considerable savings in equipment-handling operations and pier construction time. The personnel requirements for multisection lifts would remain the same with the differences being in work sequencing. The sequence for lifting several sections at one time is indicated in the multiple activities chart, Figure C-5 of Appendix C.

Table 2. Pier Construction Options

Pier Construction	Comments
Beach end to sea end (single section lifts)	Normal construction procedure for multiple section pier. The construction crane is elevated with one of the last sections to be lifted. During pier construction the crane remains on the floating sections to drive piles and position jacks. Thus, the crane is isolated on the floating sections seaward of the elevated sections.
Sea end to beach end (single section lifts)	Used when sea conditions are unpredictable. Requires the construction crane to be positioned on the beach during periods of inactivity.
Single platform (isolated)	Used when establishing work platforms not normally associated with logistics handling. A single, isolated platform lift would require the construction crane to be lifted with the platform or driven onto an adjacent floating platform prior to elevating.
Pier lengthening	Deeper draft lighterage than that envisioned during original pier construction may require greater water depths at the pierhead. This requires the pier to be extended to gain the additional water depth. Present system is designed for a maximum water depth of 20 feet. The present structural limitations prohibit extending the pier to water depths greater than 20 feet. The construction crane would be positioned on a section and lifted with the platform.
Pier widening	More than one crane may be available for handling logistics. The pier can be widened to accommodate multiple crane and logistics handling activities from both starboard and port sides of the pier simultaneously. An additional section would be positioned alongside an elevated section, piles driven, and jacks positioned. This section would be elevated using a construction crane and jack control unit positioned on the section previously elevated. This greatly simplifies the procedures of elevating additional sections for pier widening.
Combination beach end to sea end, sea end to beach end, and single platform	More than one lift system may be available for pier construction. Pier construction can proceed from the beach end and sea end simultaneously or be initiated with a single platform lift from the middle.
Multisection lifts	Several sections of a pier can be lifted simultaneously. As many as four sections can be lifted using eight jacks and two powered control units. This technique would expedite pier construction considerably. Lifts can be performed with the crane on one of the sections to be lifted, but this section must be lifted with four 50-ton-capacity jacks.

continued

Table 2. Continued

Pier Construction	Comments
Damaged section lifts	A causeway section having damaged spudwells and no driven pile can be lifted end-connected between two undamaged sections using as few as six jacks and six driven piles. The damaged spudwells and/or section can be repaired and the piles driven after the damaged section is lifted.

Multisection lift techniques were recently demonstrated and proved effective during tests at CEL in October 1976. It was determined that several sections could be lifted at one time in calm seas with two jacks attached to each section. It was also determined that a section without spudwells or driven piles (simulated spudwell damage) could be lifted end-connected between two sections having spudwells and driven piles using eight jacks. It was concluded, however, that in moderate to heavy surf conditions four jacks should be attached to each section and the lifts minimized to two sections with eight jacks or one section with four jacks. This would insure maximum lift capacity and, thereby, minimize the chance of the section/pile binding forces exceeding jack capacity during maximum surf conditions.

3.6 WORK SEQUENCING AND MANNING LEVELS FOR CAUSEWAY ELEVATION

The construction process requires a number of tasks to be performed, either sequentially or simultaneously. Often these tasks are repeated and require careful coordination with other activities. Typical concurrent operations are described in Appendix C for roadway-to-pierhead and pierhead construction.

The jack rigging operation, which begins with the attachment of the causeway sections to the pile caps with turnbuckles and ends with the final positioning of the four jacks onto the next causeway section to be elevated, took an average of 2 hours and 50 minutes. An additional hour and a half was usually required to elevate, align, and mate each causeway section to the previously elevated section. All of these tasks were basically performed serially, i.e., one task was completed before the next one could be started. It appears that the pier construction rate could be increased by paralleling the performance of various tasks.

A multiple activity diagram (Figure 17) and multiple activity charts (Figures C-1, C-3, C-4, and C-5) were constructed that described work sequencing for various combinations of four-man teams during removal, moving, and rerigging of the jacking system; disconnecting, elevating, and reconnecting of causeway sections; and positioning and driving of piles. The combinations range from two four-man teams operating with four jacks and a pile hammer up to four four-man teams operating with eight jacks and a pile hammer. The times indicated for each task were either timed directly or were estimated from video tape sequences of the Coronado test and should indicate the relative time differences between team configurations. The charts are based on the use of one truck crane, one TD-25 dozer, a rough terrain forklift, and one hydraulic crane.

Table 3 summarizes the estimated times and causeway elevation rates* for various four-man jack crew teams and jacks (four and eight) based upon estimates of the time required to perform each task as observed during the Coronado tests.

The causeway lift system mobilization and elevation activities, which began with the disassembly of the gimbals on the previously elevated section and ended with causeway section elevation and temporary connection of the section to the pile with turnbuckles, took an average of 4 hours and 20 minutes. These and other activities are shown in Figure 17. It is felt that the time to perform the lift system mobilization and causeway elevation activities could be reduced through better utilization of personnel and

*Elevation time includes all jack rigging activities and causeway end connector separation and reconnection, as well as the actual elevation process.

Table 3. Estimated Operation Times for Lifting Causeway (see note)

Teams	Jacks	Time per Causeway Section (hr)	Time to Construct a Ten-Section Pier (hr)
1	4	4.33	43.3
2	4	3.08	30.8
3	4	2.50	25.0
4	4	2.42	24.2
4	8 (2 cws[a])	1.58	15.8
4	8 (3 cws[b])	1.06	12.0[c]

[a]Two causeway sections end-connected.

[b]Three causeway sections end-connected.

[c]Nine causeway sections at 1.06 hr/section plus one section at 2.42 hr/section.

Note: Estimates obtained from study by Human Factors Division, NELC.

by increasing the number of jack crew teams and jacks, as shown in Table 3 and Appendix C. Further reductions in the time required to perform these activities should be realized by reducing individual activity times through incorporation of the suggested improvements presented in this report.

For a ten-section pier, the activity rate could be increased by a factor of 3.6 by using four lift system teams and eight jacks and paralleling the performance of various activities. It was assumed that the pile placement and driving activities could be performed during those periods when the truck crane was not required for transporting and mounting jacks onto piles.

3.7 PERSONNEL ORGANIZATION AND TRAINING

Appendix B covers in detail each of the tasks required to construct an elevated pier system. The integration of these tasks into an efficient and safe operation requires a great deal of planning, training, and organization. The latter two, training and organization, are the primary areas that can produce significant improvements in the pier construction operation.

Each member of the construction crew should be trained in detail for his assigned task and also given a general coverage of the overall project. The details should be defined down to the type of knots to tie and the type of turnbuckles to use for each task and each situation. Each task should be related to other work so that all the team members understand the exact sequence of the activities and how each activity will affect the accomplishment of others that are occurring in parallel or series with it (multiple activities). It is extremely important to establish a standard technique for each task and adhere to that technique right through to the end of the operation. The sequence of tasks should also be firmly established and should be varied only if absolutely necessary, such as with equipment failure or adverse weather. Consistency in these areas will permit each team and all team members to function efficiently and safely, because they will know exactly what to expect during all phases of the operation.

The organization of the construction personnel into teams with supervising team leaders is essential to a successful operation. The team leaders should be responsible to the construction supervisor who oversees the entire operation. The integrity of the teams should be maintained for each major phase of the operation, and all team reorganizations during the operation should be planned and understood beforehand by each member of the reorganized team. Diverting team members to perform random tasks should be discouraged, especially when the team member is engaged in his assigned task. Breaking off team members seriously interferes with the progress and sequence of the construction. The recommended minimum personnel requirements are indicated in Table 4 for each activity; personnel and equipment are summarized in Table 5.

With the above suggestions and those in Appendix B, construction rates of from two to six causeway sections per day should be attainable.

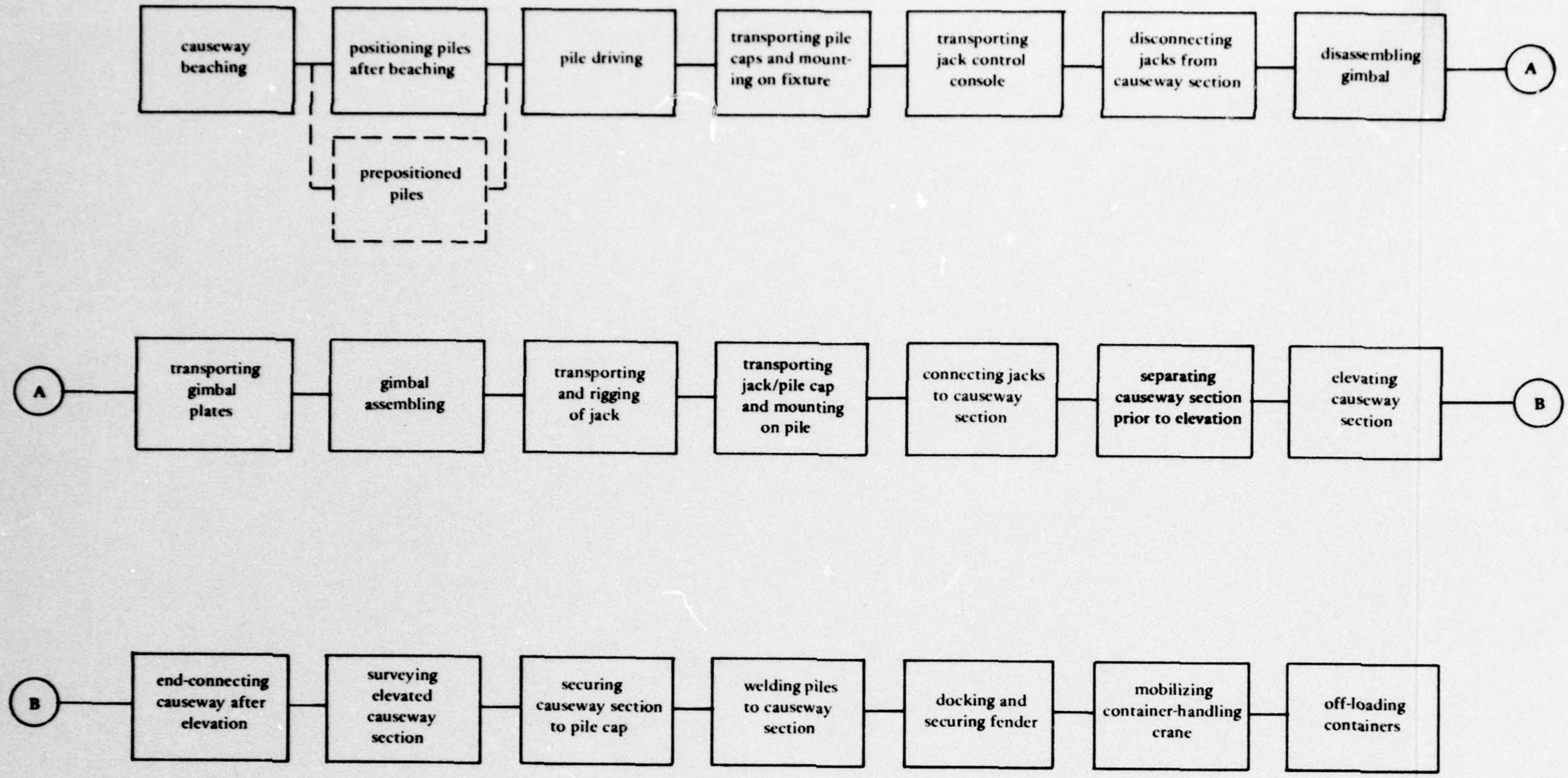


Figure 17. Activity diagram for lift system mobilization and causeway elevation.

Table 4. Recommended Minimum Personnel Requirement for Pier Construction/Retrieval Activities[a]

Activity	No. of Personnel Required								
	OIC[b]	EO/C[b]	EO2	EO3	SW3/SWCN	SN/SR	EA	RM	Total
Construction									
Causeway beaching	1	1				6	3	3	13
Positioning pile after beaching			2			4			6
Prepositioning piles			2		4	4			10
Pile driving		1	2	2		2			7
Lift system mobilization		2	4	2		16			24
Elevating causeway section activities	1	1	2	1		7			12
Surveying the elevated causeway section			1	1		4	3		9
Securing causeway section to pile caps		1				8			9
Permanent connection of causeway section to piles					6	6[c]			6
Retrieval									
Lift system mobilization activities		2	4	2		18			26
Causeway section lowering activities	1	1	2	1		7			12
Pulling of piles		1	2	1	1	5			10
Largest complement needed for any one activity	1	2	4	2	6	18	3	3	39

[a]Based on equipment, methods, and procedures employed during the Coronado tests.

[b]Involved in overall supervision of all tasks.

[c]Recommend pinned connection; requires six SN/SRs and six SW3/SWCNs.

Table 5. Summary of Personnel Requirements, Team Organization, and Equipment Requirements for Pier Construction/Retrieval

Team	Personnel		Equipment	
	Rank	No.	Type	No.
General				
Beach Commander	LT (OIC)	1		
Communication	RM	3	Radios, UHF 406-419 MHz	4
Surveyor	EA	3	Level/rod	1
Welder/Burner	SW3/SWCN	6	Arc welder, 300 ampere; oxyacetylene	2
Elevated Section				
Supervisor	EO/C	1		
Equipment Operator	EO/2	1	Hydraulic crane, 5-ton capacity, 34-foot boom	1
Rigger	SN/SR	8	Rough terrain fork truck, 3-ton capacity; Crawler tractor, TD-25, 100,000-pound winch capacity	1
Jacking				
Equipment Operator	EO2	1	Powered lift system control console and five 50-ton-capacity jacks	1
Equipment Operator/ Signalman	EO3	1		
Rigger/Observer	SN/SR	4		
Floating Section				
Supervisor	EO/C	1		
Equipment Operator	EO2	2	Crane, 35-ton capacity, 80-foot boom	1
Equipment Operator/ Signalman	EO3	1	Pile hammer, DE-30 diesel	1
Rigger/Observer	SN/SR	6		
TOTAL		39		

SECTION 4

DISCUSSION

A general discussion of the overall operations is included herein. Detailed discussions of specific activities can be found in Appendix B.

4.1 SPUDWELLS AND PILE GUIDES

The internal and external spudwells that were developed to provide the NL P-Series pontoon system with an elevating capability performed satisfactorily. The internal spudwells allowed the pierhead sections to be joined side by side and the pile to be cut off close to the deck [within 10 inches (254 mm) or flush] for truck traffic clearance. The steel gusset that was welded between the pile and the spudwell restricted the pile to being cut about 10 inches (254 mm) above the deck. The external spudwells allowed two-way traffic on the roadway sections from the beach. The external spudwells also performed very well in positioning and holding the piles for the fender system at the pierhead.

Pile guides were tested for use when installing and driving fender piles. With the guide installed, the pile was held in a more vertical alignment during and after driving. This vertical alignment of the pile was considered desirable for fender system operation.

4.2 ELEVATED CAUSEWAY INSTALLATION/ RETRIEVAL

The same lift system and equipment were used to elevate the pontoon sections during the Phase I tests conducted in June-July 1975 at Port Hueneme as were used in the Phase II tests conducted at Coronado. However, only four pontoon sections and one fender string were involved in the Phase I tests.

Pile driving and elevating of causeway sections were conducted during the Phase I tests. About 5 days were involved in installing the four sections at Port Hueneme.* The pier installation included: beaching the sections, driving the piles, elevating the sections to proper height above the water with the lift system, connecting the chain/turnbuckles to hold padeyes, and making the pile-to-causeway connection. With the training gained during the pier installation, it was estimated that the crew could install the four sections in one 12-hour day. It took 2 days to lower and remove the sections from the beach. The results of this test demonstrated the feasibility of the components to perform the required concept functions, and it was recommended that the Phase II tests be conducted.

During the Phase II tests, establishing procedures and training the military crew were involved during most of the elevating period. When rough water [6-1/2-foot (2-m) breakers] was encountered, the pile setting and driving were slowed or stopped for safety reasons. An example of a planned delay in operation/ procedures was the stopping of the pile driving crew to await the elevating crew's disconnection of the end connectors. This was not a normal delay as the sections can be connected or separated while piles are being driven, or have been driven in other sections. However, having a 10-man crew inactive for several hours did not delay the elevating operation, as the pile-driving operation proceeded more rapidly than the elevating. Thirteen days (12 to 26 November, excluding 15-16 November) were required to install nine sections. Accounting for the planned delays and other nonoperation periods, the actual time to install the nine sections, including the fender system, was about 66 hours, or 7.3 hours per section. During the latter part of the operation, it was estimated that training had improved crew operations to the level that sections could be installed at a rate of one every 4 hours.

The nominal depth for driving the piles was 10 feet (3 m) into the sand bottom. A pier settlement of about 0.8 inch (20 mm) was measured during the elevating and container-handling tests. A check made just prior to retrieving the pier on 5 January 1976 showed an increase to about 1.5 inches (40 mm). The pier settlement was fairly uniform overall.

*Phase I tests were conducted with an all-civilian crew.

Six days (5 to 10 January 1976) were involved in retrieval, i.e., lowering the nine sections (including removing the fender system) and pulling the piling. Five sections of the approach roadway (No. 6, 7, 8, 9, and 10) were lowered simultaneously while end-connected. It took about 7 hours to lower these five sections. Forty-one hours were spent during the 6 days to lower the nine sections.

4.3 ENVIRONMENTAL DATA*

During the Phase I test period, two tropical storms occurred off the coast of Mexico that generated heavy swell at the test site at Port Hueneme. On 7 and 8 July, breakers in excess of 8 feet (2.5 m) were noted. The breakers approached the pier at 5-to-30-degree angles, and, on occasion, swells struck the pier from two directions simultaneously. The breakers imparted more severe motions to the crane boom, piling, and pile hammer than occurred during the Phase II tests. The short length of the four-section pier and the construction procedure (installing from seaward end toward the beach) also increased the motion problem and working hazard during the Phase I tests. Waves were frequently breaking across the floating sections during the elevation operation.

Swells and breakers were relatively minor during the Phase II operation. There were only 2 days during pier construction that breakers up to 5.5 feet (1.7 m) were observed.

4.4 HUMAN FACTORS

The Naval Electronics Laboratory Center (NELC), San Diego, conducted a human engineering study of the elevated causeway installation/retrieval and container-transfer operations. The emphasis of this study was placed on improving man/equipment interactions and in developing personnel requirements. The task activities performed by the crews were identified by direct observation and review of video tape recordings taken during the Coronado tests. An analysis was then made to identify man/equipment problem areas and possible solutions. Attention was given to personnel numbers, skill levels, and their utilization. Personnel hazards were also identified, and suggested methods of correcting them are presented.

Areas for improvement are suggested in the jack rigging operation, particularly for gimbal assembly and pile cap handling. Other items discussed include: alternate methods of securing piles to the causeway sections to reduce causeway section elevating time; personnel and equipment requirements; prepositioning of piles in spudwells for transport to the beach site, along with alternate methods of pile attachment; and improved crew allocations. These human factor items are covered in detail along with an engineering analysis of each activity, recommendations, and personnel requirements in Appendix B.

*Environmental data are presented in detail in Volume 1.

SECTION 5

FINDINGS

In general, it was found that the elevated causeway system in its present form can be used by Naval construction teams. Also, a relatively small group of Naval construction personnel can be trained sufficiently to construct a pier system without the use of sophisticated training techniques and/or aids.

Several findings point out marginal areas of the construction process that deserve further investigation and/or define correctable weaknesses and strengths in hardware and methods. They are:

- The possibility of lifting more than one section at a time exists.
- Positioning piles in spudwells within the surf zone is very hazardous to personnel.
- Current methods of securing pontoon sections to piling are cumbersome.
- Methods of aligning the pier prior to dropping and driving the piles were not used, but should be developed.
- Inadequate communications existed during the beaching of the causeway and dropping of the first pipe pile.
- Pile hammer pendulation and possible damage to crane boom is a limiting factor when driving piles.
- The handling of gimbal assemblies is difficult and dangerous when installing them on external spudwells.
- Pile guides for the fender's external spudwells are desirable.

The following three areas were found to be satisfactory:

- Methods of handling the jack lift chain and recycling the jacks.
- Sequence of pier construction (shore to sea).
- Method of disconnecting sections and connecting sections.

Specific findings for each activity of pier construction are analyzed in Appendix B of this report and summarized in Table 6.

Table 6. Summary of Appendix B Recommendations for Pier Construction and Retrieval

Activity	Personnel			Methods and Equipment	Safety
	Title	Rate	No.		
PIER CONSTRUCTION					
Causeway Beaching	Supervisor Equipment Operators (Bulldozers) Radio Operators Line Handlers Leadman (causeway) Survey/Sounding Party	EOC EO3 RM SR SN EA	1 2 3 5 1 3	Adequate communications among the beaching officer, the sounding survey party, bulldozer operators, warping tug captain, and pile-dropping personnel must be maintained. Causeway should be pulled onto the beach as far as possible.	
Positioning Piles at Sea	Steelworkers Crane Operator Supervisor/Signalman Tagline Handlers/Riggers	SW3/SWCN EO2 EO2 SN/SR	4 1 1 4	Piles should be transported in vertical position during beach approach. Pinning method of securing piles in the spudwells during transport should be used.	
Positioning Piles After Beaching	Crane Operator Supervisor/Signalman Tagline Handlers/Riggers	EO2 EO2 SN/SR	1 1 4	Develop a device and/or method that will enable tagline handlers to apply greater force to pile in the plane of the crane boom axis.	Tagline handlers should stay clear of the spudwell and the pile during pile insertion.
Pile Driving	Supervisor Crane Operator Supervisor/Signalman Throttle Control Operator Stop Line Handler Hammer Tagline Handlers	EOC EO2 EO2 EO3 EO3 SN/SR	1 1 1 1 1 2	Develop a device/method to reduce pile pendulation. Develop methods to obtain complete site soil survey data prior to determining optimum pile drive depths. Operation of the pile-driving hammer should be checked out prior to transporting to the beach location. A means of protecting the hammer from salt spray during transport should be provided. A checklist for hammer operations should be devised, including a pre-operational checkout.	The cause of hammer lead structural failures should be remedied.

continued

Table 6. Continued

Activity	Personnel			Methods and Equipment	Safety
	Title	Rate	No.		
Lift System Mobilization					
Transporting Pile Caps and Mounting on Fixture	Supervisor Forklift or Hydraulic Crane Operator Rigger	EOC EO2 SN/SR	1 1 1	Develop methods of attaching causeway section to pile, eliminating pile caps.	
Transport of Jack Control Console	Signalman Hydraulic Line Handlers Console Operator/Supervisor	EO3 SN/SR EO2	1 4 1	Develop a self-propelled jack control console. A fixed procedure should be developed for hydraulic line transport and placement.	
Disconnecting Jacks From Causeway Section	Riggers	SN/SR	4	Improve gimbal assembly hardware and methods.	
Gimbal Disassembly	Riggers	SN/SR	4	See recommendations given for the gimbal assembly subtask of the jack rigging activity.	
Transporting Gimbal Plates From an Elevated Causeway Section to a Floating Section	Signalman Crane Operator Riggers	EO3 EO2 SN/SR	1 1 8		
Assembling the Gimbals	Supervisor Riggers	EOC SN/SR	1 4	Improve gimbal hardware and assembly methods.	Provide a stand with guard rails to allow assembly of the outboard gimbal sections.

continued

Table 6. Continued

Activity	Personnel			Methods and Equipment	Safety
	Title	Rate	No.		
Transporting and Rigging of Jacks	Control Console Operator/ Supervisor Hydraulic Crane Operator Riggers	EO2 EO2 SN/SR	1 1 4	A method of accurately determining the required length of chain from jack to gimbal for each pile should be utilized.	All crew members should understand thoroughly the inherent danger of snagging chains on the elevated causeway when transferring jacks, and snagging chains on the floating causeway once the jack has been mounted on the pile.
Transporting Jack/ Pile Cap and Mounting on Pile	Supervisor Signalman Crane Operators Riggers	EOC EO3 EO2 SN/SR	1 1 2 10	The chains and hydraulic lines should be cleared prior to engaging the crane hook. The ends of the chains should be loosely tied together.	
Connecting Jacks to Causeway Section	Supervisor Observers Riggers	EOC SN/SR SN/SR	1 3 3	Develop a method for attaching the jack chain gimbal that does not require the rigger to work outboard.	Provide a stand with guard rails for riggers working outboard.
			Causeway Section Elevation		
Causeway Section Separation Prior to Elevating	Supervisor Console Operator Signalman Riggers	EOC EO2 EO3 SN/SR	1 1 1 3	Develop a means of reducing the possibility of end connector binding. Investigate methods of elevating more than one section at a time using four or more jacks.	
Causeway Section Elevation	Console Operator Signalman Observers	EO2 EO3 SN/SR	1 1 4	Develop a manual over-ride control for each jack that is operated by the observer of each jack. Develop an alternative method of separating the end connectors. Develop a scheme that utilizes and expands upon the "scissoring" technique.	The free end of the slack idle chain should be attached to the gimbal assembly with a 1/2-inch nylon line at all times during jack operation. This line should not be excessively slack at any time, and the slack should never be removed during jack operation.

continued

Table 6. Continued

Activity	Personnel			Methods and Equipment	Safety
	Title	Rate	No.		
Connection of Elevated Causeway Sections	Supervisor Equipment Operator (Bulldozer) Console Operator Signalman Riggers	EOC EO2 EO2 EO3 SN/SR	1 1 1 1 4	Provide a means of protecting the wooden deck against bulldozer damage or provide a different type of decking material. An alternative to the use of a bulldozer should be investigated.	Personnel should remain clear of the area as tension is applied to the cable during alignment and connection of the elevated causeway sections.
Surveying the Elevated Causeway Section	Console Operator Signalman Surveyors	EO2 EO3 EA	1 1 3	Develop an alternative method of surveying to reduce personnel requirements.	Four riggers are required to observe jacks during final adjustment of sections.
Securing Causeway Section to Pile Cap:	Supervisor	EOC	1	A hooked rod should be used during final tightening of the turnbuckle.	Safety harness should be used whenever working on the outboard side of the spudwell.
Less than 5 feet above deck	Riggers	SN/SR	4	Turnbuckles, detachable links, or shackles should be prepositioned on the causeway section.	
Between 5 and 7 feet above deck	Riggers	SN/SR	6	Develop a causeway/pile attachment method (pile pinning) that eliminates the need for the temporary pile cap/causeway section connection and possibly the welding operations.	
More than 7 feet above deck	Riggers	SN/SR	8		
Permanent Connection of Causeway Section to Piles:	Welder/Supervisor	SW3	1	Welding operations should lag elevation of the causeway sections by two sections.	The stands for over-the-side welding should be approximately 2 feet wide and have a safety rail.
Welded Connection	Welders	SWCN	6	Quieter generators should be used or the present ones acoustically modified to reduce the noise level. Equipment should be put away or covered when not in use.	
Pinned Connection	Riggers	SN/SR	6	Pin connection is recommended for development.	

continued

Table 6. Continued

Activity	Personnel			Methods and Equipment	Safety
	Title	Rate	No.		
PIER RETRIEVAL					
Removing the Gusset Plates	Welder/Supervisor Welders	SW3 SWCN	1 3	Cutting should be two sections ahead of lowering. An alternative means of connecting piles to causeway sections should be investigated.	Stands for over-the-side cutting should be 2 feet wide and have a safety rail.
Lift System Mobilization					
Transport of Jack Control Console	Console Operator/Supervisor Signalman Line Handlers	EO2 EO3 SN/SR	1 1 4	Develop a self-propelled jack control console. A fixed procedure should be developed for hydraulic line transport and placement.	
Disconnecting Jacks From Causeway Section	Supervisor Riggers	EOC SN/SR	1 4	Improve gimbal hardware and assembly methods. Develop a jack chain gimbal attachment method that does not require the rigger to work outboard.	Provide a stand for riggers working outboard.
Gimbal Disassembly	Supervisor Riggers	EOC SN/SR	1 4	Improve gimbal hardware and assembly methods.	Provide a stand with guard rails to allow disassembly of the outboard gimbal sections.
Transporting Gimbal Plates:					
Lowering Separated Sections	Crane Operator Signalman Riggers	EO2 EO3 SN/SR	1 1 8		
Lowering End-Connected Sections	Signalman	EO3	1	Lower end-connected to eliminate crane and four riggers.	

continued

Table 6. Continued

Activity	Personnel: Title	Personnel: Rate	Personnel: No.	Methods and Equipment	Safety
Gimbal Assembly	Supervisor Riggers	EOC SN/SR	1 4		Provide a stand to allow assembly of the outboard gimbal sections.
Removing Jack From Pile	Supervisor Signalman Crane Operators Riggers	EOC EO3 EO2 SN/SR	1 1 2 6	Keep chains and hydraulic lines clear at all times. Tie ends of chains loosely together.	
Rigging of Jack and Mounting on Pile	Supervisor Signalman Crane Operators Riggers	EOC EO3 EO2 SN/SR	1 1 2 8		
Connecting Jacks to Causeway Section	Supervisor Riggers	EOC SN/SR	1 4	Develop a method for attaching the jack chain gimbal that does not require the rigger to work outboard.	Provide a stand for riggers working outboard.
Removing Pile Caps and Associated Hardware	Hydraulic Operator Riggers	EO2 SN/SR	1 8	Remove hardware from causeway to keep area clear.	
Causeway Section Lowering					
Causeway Section Separation Prior to Lowering	Supervisor Signalman Console Operator Equipment Operator (Bulldozer) Riggers	EOC EO3 EO2 EO2 SN/SR	1 1 1 1 4	Investigate methods of lowering all sections end-connected. Develop methods of lowering that reduce the possibility of end connector binding. Develop an alternative method of separating the end connector. Provide a means of protecting the wooden deck against bulldozer damage or provide a different type of decking material.	

continued

Table 6. Continued

Activity	Personnel			Methods and Equipment	Safety
	Title	Rate	No.		
Lowering of Causeway Section	Console Operator	EO2	1	Develop a manual over-ride control for each jack.	
	Signalman	EO3	1	Develop an alternative method of separating the end connectors.	
	Observers	SN/SR	4	Develop a scheme that utilizes and expands upon the "scissoring" technique.	
Causeway Section End-Connected After Lowering	Supervisor	EOC	1	Develop a means of reducing the possibility of end connector binding.	
	Signalman	EO3	1		
	Console Operator	EO2	1		
	Equipment Operator (Bulldozer)	EO2	1		
	Riggers	SN/SR	4		
Pulling of Piles	Supervisor	EOC	1	Devise method to control pendulation of piles when carried by crane.	Keep all personnel clear of working area when crane is swinging piles.
	Signalman	EO2	1	Set crane up at every pile (do not pull from a distance).	
	Crane Operator	EO2	1		
	Equipment Operator (Hydraulic Crane)	EO3	1		
	Welder	SWCN	1		
	Riggers	SN/SR	5		

SECTION 6

CONCLUSIONS

The pier construction and retrieval system could be improved in terms of reductions in the time necessary to accomplish many of the tasks through better utilization of personnel and adjustments in methods and equipment. Hazards to personnel and potential damage to equipment can be eliminated or minimized through adjustments in the methods, introduction of safety devices, development of standard procedures, and increasing the safety consciousness of all personnel.

A restructuring of the lift system mobilization activities through augmentation and better utilization of personnel/equipment could significantly increase the pier construction rate. Multiple activity charts that describe work sequencing for various combinations of lift system teams and jacks are given in Appendix C.

Based on the results of these tests it was concluded that a truck crane with a 35-ton (31.8-Mg) rated lift capacity and a 70-foot (21.1-m) minimum length boom is required for the installation, elevation, and demobilization of the elevated causeway system. A smaller capacity or shorter boom crane would not be able to handle all the required assignments. A crane having a boom length of 80 feet (24.2 m) would be better suited for driving piles to depths exceeding 15 feet (4.5 m).

It was also concluded that the minimum support equipment assets must include a 5-ton (4.5-Mg) capacity hydraulic crane having a minimum reach of 34 feet (10.4 m), two TD-25 or equivalent crawler tractors having a wire rope winch of 50 tons (45.3 Mg) capacity, and one wire rope sheave compatible with the crawler tractor's winch.

It is concluded that at least 39 construction personnel are required to perform the tasks of pier construction or retrieval. These personnel should be separated into a general team and three major construction teams as cited in Table 5. With the augmentation of the best construction methods and optimum utilization of personnel, construction rates of one elevated causeway section in less than 3 hours using four jacks and four teams are attainable. It is further concluded that multisection lifts are technically feasible under ideal conditions and should be developed. With the multisection lifting methods, which use eight or more jacks, construction rates could be reduced to one elevated section in approximately 1 hour.

SECTION 7

RECOMMENDATIONS

The following general investigations are recommended that should significantly improve system components and operation/safety procedures.

- Investigate multisection lift technique.
- Investigate pile positioning in spudwells at sea.
- Investigate methods of securing pontoon sections to piling.
- Investigate site survey and pier construction survey techniques.
- Investigate methods for aligning the pier prior to dropping and driving piles.
- Investigate simplification and possible automation of lift system.

These general recommended investigations are amplified and clarified in Table 7.

Table 7. Summary of Recommendations for Pier Construction and Retrieval

Activity	Recommendation
Causeway Beaching	Adequate communications between the beaching officer, the sounding survey party, bulldozer operators, warping tug captain, and pile-dropping personnel must be maintained. Causeway should be pulled onto the beach as far as possible.
Positioning Piles at Sea	All piles should be transported in vertical position during beach approach. The piles should be secured in the spudwells by pins. The external spudwell-to-causeway connection should be modified such that the connection will not work loose with repeated loadings.
Positioning Piles After Beaching	Develop a device or method to reduce pile pendulation, particularly in the plane of the crane boom axis. Tagline handlers should stay clear of the spudwell and the pile during pile insertion.
Pile Driving	Develop a device or method to reduce pile hammer pendulation, particularly in the plane of the crane boom axis. Operation of the pile-driving hammer should be checked out prior to transporting to the beach location. A means of protecting the hammer from salt spray during transport should be provided. A checklist for hammer operations should be devised, including a pre-operational checkout. The cause of hammer lead structural failures should be investigated and remedied. A complete site soil survey should be made to determine optimum pile drive depths.
Jack Rigging: Transporting Pile Caps and Mounting on Fixture	Possible injury can be reduced by providing a mechanical means of lifting, transporting, and mounting pile cap. An alternate method of attaching causeway section to piles, such as a pin connection that would replace the pile cap connection scheme, should be developed.
Transport Control Console	A protective cage should be provided to protect the hydraulic connectors on the jack control console. A self-propelled power unit/control console should be developed to eliminate the need for a hydraulic crane to perform this task.

continued

Table 7. Continued

Activity	Recommendation
Disconnecting Jacks From Causeway Section	Gimbal assemblies should be modified to incorporate improved connection components for ease of assembly. A safety harness should be used by riggers when working outboard on the external spudwells.
Jack Rigging: Gimbal Disassembly	A gimbal assembly/disassembly personnel ramp should be provided for assembling the outboard gimbal sections on the external spudwell. Gimbal assemblies should be modified to incorporate improved causeway sections to gimbal connector components.
Jack Rigging: Transporting Gimbal Plates	Modify the gimbals to minimize handling problems without sacrificing structural integrity and mechanical effectiveness.
Jack Rigging: Gimbal Assembly	See recommendations for Gimbal Disassembly subtask of Jack Rigging activity.
Jack Rigging: Transporting and Rigging of Jacks	Present method of determining the required length of chain from jack to gimbal for each pile should be retained. Present method of recycling jack should be retained. Chain should be clearly marked at intervals with durable paint.
Jack Rigging: Transporting Jack/Pile Cap and Mounting on Pile	Clear the chains and hydraulic lines prior to engaging the crane hook. The ends of the chains should be loosely tied together. A jack having slack chain in contact with the gimbal assembly, spudwell, or pontoon structure should never be left unattended.
Jack Rigging: Connecting Jacks to Causeway Section	Develop a method for attaching the jack chain gimbal that does not require the rigger to work outboard. Improve and simplify the chain-to-gimbal connection. Provide a ramp for riggers working outboard on the external spudwell.
Causeway Section Separation Prior to Elevating	The horizontal curvature in a beached floating causeway induced by long shore currents should be corrected using bulldozers, warping tugs, and broaching wires prior to dropping and driving of piles.
Causeway Section Elevation	The free end of the slack idle chain should be attached to the gimbal assembly with nylon rope at all times during jack operation. Combinations of automatic, semi-automatic, and manual override jack controlling functions should be explored that would best meet the requirements of the environment and personnel.

continued

Table 7. Continued

Activity	Recommendation
Causeway End Connector After Elevation	Develop a scheme that utilizes and expands upon the "scissoring" technique. Provide a means of protecting the wooden deck against bulldozer damage or provide a different type of decking material. An alternative to the use of a bulldozer should be investigated. Personnel should remain clear of the area as tension is applied to the wire rope cable during final connection alignment.
Surveying the Elevated Causeway Section	Develop an alternative method of surveying to reduce personnel requirements. Re-evaluate surveying precision requirements.
Securing Elevated Causeway Section to Pile	A hooked rod should be used during final tightening of the turnbuckle. Safety harnesses should be used whenever working on the outboard side of the spudwell. Turnbuckles, detachable links, or shackles should be prepositioned on causeway sections. Develop a causeway/pile attachment method, such as a pinned connection, that will eliminate the need for the temporary pile cap/causeway section connection and possibly the welding operations.
Permanent Connection of Causeway Section to Piles	Welding operations should lag elevation of the causeway sections by two sections. Quieter generators should be used or the present ones acoustically modified to reduce the noise level. Equipment should be put away or covered when not in use. An alternate means of connecting piles to the causeway sections, such as the pinned connection, should be investigated. The stands for over-the-side welding should be approximately 2 feet wide and have a safety rail.

SECTION 8

ACKNOWLEDGMENTS

The following organizations provided direction, equipment, experience, and personnel necessary to achieve the excellent results, information, and satisfactory conclusion of the advanced development tests. Without their cooperation and support the program could not have been accomplished.

- Commander, Naval Surface Forces, Pacific authorized the Amphibious Units to support the program.

- Commander, Naval Beach Group, Amphibious Refresher Training Group, Coronado, approved and coordinated the beach support operations.

- Amphibious Construction Battalion One provided the personnel and equipment to direct, install, and operate the elevated causeway.

- Amphibious Assault Craft Unit One furnished the LCU landing craft and crews used to ferry the containers.

- First Force Service Regiment, First Marine Division, Camp Pendleton, California, provided the drivers and truck/trailers used to move the containers on the causeway.

- Naval Ship Research Development Center, Carderock, Maryland, conducted the motion measurements and analysis for the lighters moored to the pierhead.

- Naval Electronics Laboratory Center, Human Factors Division, San Diego, provided the human engineering study of the elevated causeway system.

- Public Works Center, U.S. Naval Station, San Diego, fabricated the spudwells, installed and load tested the external spudwells, and provided welders during the operation.

- Construction Equipment Department and Marine Terminal Division, NCBC, Port Hueneme, assembled all of the pierhead pontoon sections.

- Transportation Division, NCBC, Port Hueneme, provided operators and a construction crane for both the Phase I and Phase II tests.

SECTION 9

REFERENCES

1. Civil Engineering Laboratory. Plan for Advanced Development Tests – COTS. Port Hueneme, Calif., Aug 1975.

2. ———. Preliminary Report (in-house); "Container Off-Loading and Transfer System, Advanced Development Tests," Sep 1975.

3. ———. Movie, FA/LDH-501, 16 mm, sound, color, 22 minutes, "Container Off-Loading and Transfer System" (Phase I tests).

4. ———. Movie, 16 mm, sound, color, 25 minutes, "Elevated Causeway Advanced Development Tests," (Phase II tests), Nov 1975.

5. ———. Technical Report R-826: Lift System for Elevated Causeways," by C. I. Skaalen. Port Hueneme, Calif., Nov 1975.

6. ———. Movie, FA/LDH-604, 16 mm, sound, color, 8 minutes, "COTS Elevated Causeway System – Fender System," (Phase II tests), Nov 1975.

Appendix A

PILE LENGTH DETERMINATIONS AND PIER SETTLEMENT SURVEY FOR PHASE II TESTS

PILE LENGTH DETERMINATION

In determining the lengths of various piling, several criteria had to be met.

(1) Piles to be driven to a minimum pile set of four blows per inch to obtain the stability/resistance required to safely support the temporary pier (Figure A-1).

(2) Piles to be driven as much as 15 feet (4.6 m) into the soil using the DE-30 diesel pile hammer without consuming excessive valuable pier construction time and/or requiring long piles, which are difficult to handle.

(3) A maximum of 35 feet (10.7 m) of pile to show above the deck after the pile has been placed in the spudwell and is resting on the ocean bottom.

(4) To insure pier survival during a high tide storm, the bottom of the pier at the pierhead to be at least 15 feet (4.6 m) above mean low water.

(5) A minimum of 3 feet (0.9 m) of pile to show above deck after sections are elevated into position to allow for installation of rigging hardware between pile cap and causeway section.

(6) A maximum of 7 feet (2.1 m) of pile to show above deck after sections are elevated into position to allow manual attachment of rigging hardware between pile caps and elevated sections; eliminates need for crane.

(7) A slope in pier roadway is required such that with the use of several pontoon roadway sections, a pier height above mean low water of at least 15 feet (4.6 m) to be obtained without logistically burdensome beach ramps, sheet piling, or sand ramp constructions.

Soundings, assumptions, and calculations for pile length determinations and drive depths are shown in Table A-1. Minimum and maximum water depths that could be contended with using prepositioned piles of predetermined lengths selected on the basis of pre-exercise surveys were calculated on the basis of the seven criteria previously cited. During the beaching it was quickly determined by actual soundings if the minimum/maximum water depths existed beneath the various causeway sections. The allowable pile drive depths were calculated (Table A-1) after it was determined that the pile lengths and locations in conjunction with the actual water depths met the seven criteria. The pile bearing capacities were determined during driving by noting the pile set. In most cases a minimum set of four blows per inch was achieved (Figure A-1). Actual procedures for accomplishing the pile driving to various depths and detailed discussions of various activities in construction of the nine-section NL pontoon causeway pier are discussed in Appendix B.

PIER SETTLEMENT SURVEY AND ANALYSIS

A survey of the height of the causeway deck at each of the corner piles was begun during the latter part of the elevation and continued until retrieval was initiated. This survey determined the amount and location of pile settlement which occurred during different phases of construction and operation. This information will be useful as a basis for determining where additional piles or increased pile drive depths might be necessary.

During preparations for pier construction, a benchmark was established near the site to provide a permanent reference for the settlement survey. Surveys were taken on 12 occasions; six during elevation, four during operations, and two during the period of no activity before retrieval. The survey was performed by noting the difference in height of the benchmark and the height of the deck next to the piles sighted.

The original rate of settlement was approximately 0.004 foot (0.122 cm) per day. This was during the construction and operational phases when heavy

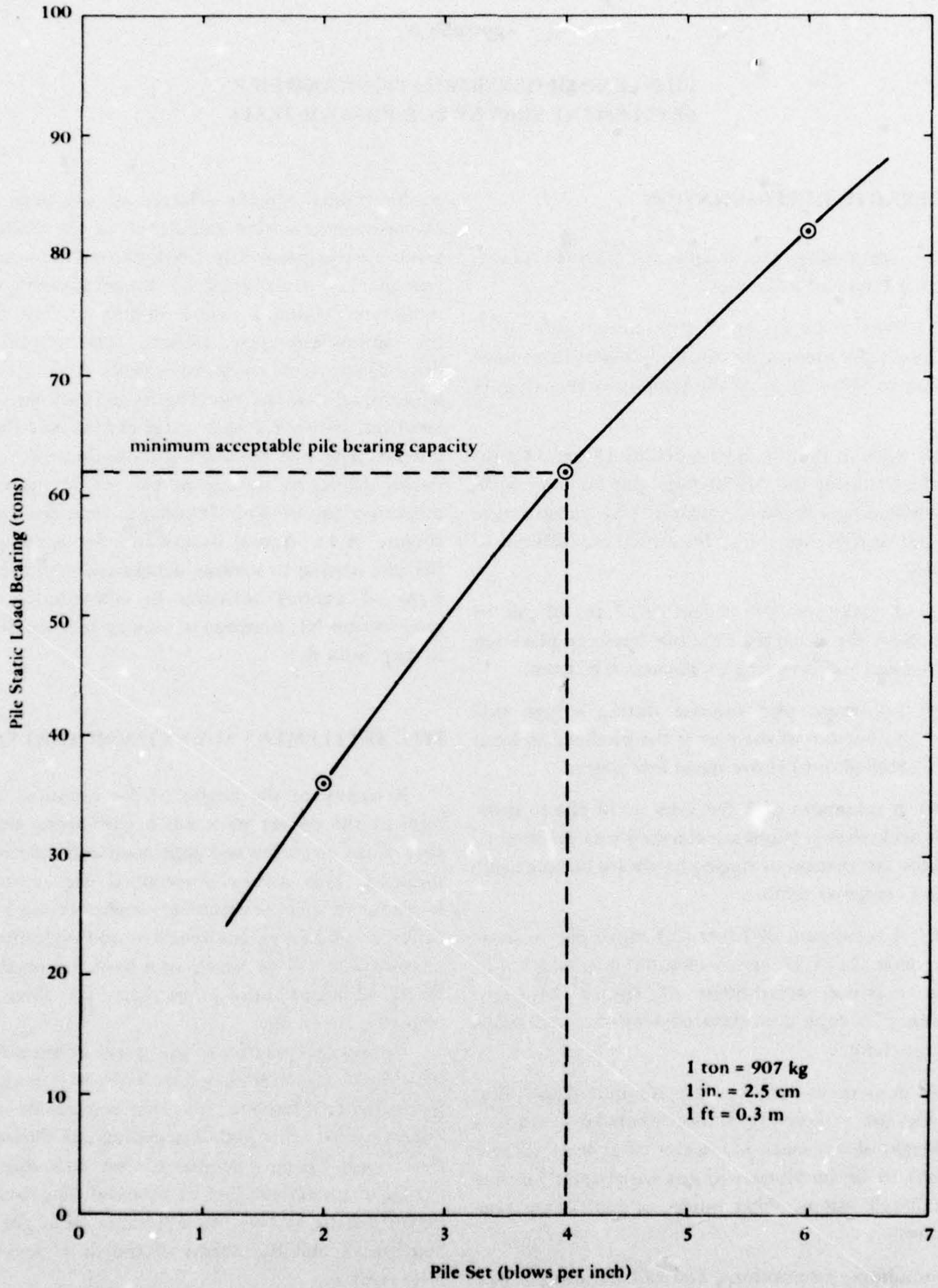


Figure A-1. Pile load bearing (MKT DE-30, 8-foot stroke).

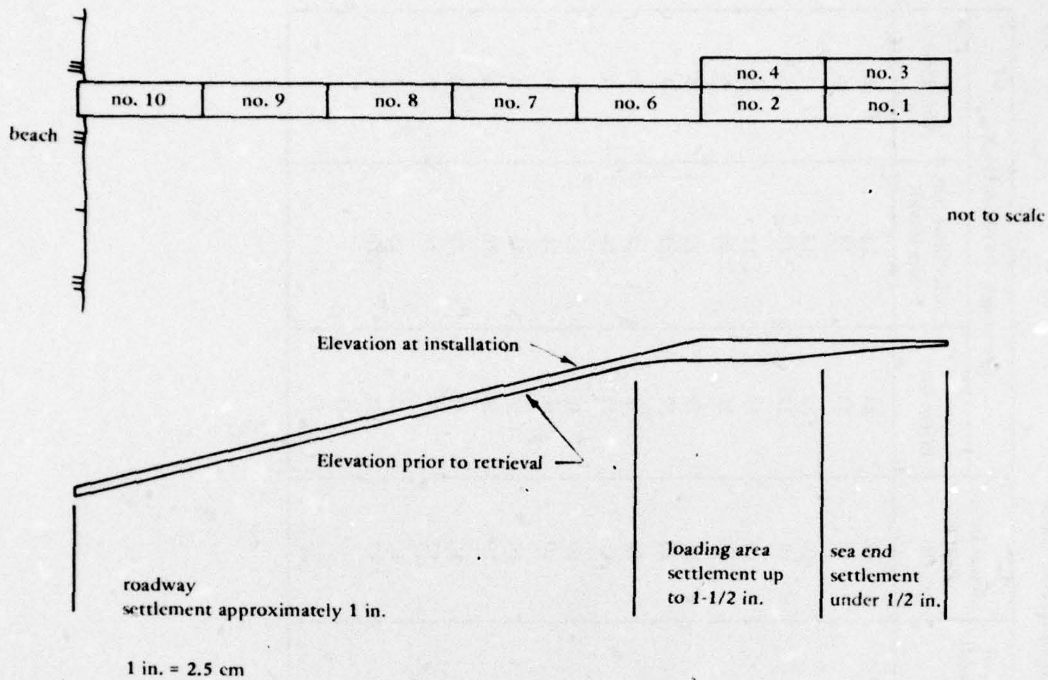


Figure A-2. Pier settlement.

traffic and loads were present. This rate was gradually reduced to 0.001 foot (0.03 cm) per day during the 3 weeks of inactivity prior to removal.

The total settlement of a section varied with the amount of traffic and load that section had been subjected to. The area with the least activity was at the seaward end of the pierhead. This end showed an average total settlement of under 1/2 inch (1.27 cm). The highest load and traffic area was located at the truck-loading point on the pier. Maximum settlement here was 1-1/2 inches (3.81 cm). Along the sloped roadway sections the average total settlement was approximately 1 inch (2.54 cm) (see Figure A-2).

Soil samples taken from the bottom of the piles as they were pulled indicated that the composition of the soil was soft, silty sand.

In preparing pile driving plans for the construction of a causeway pier it is recommended that a study be made of the proposed traffic patterns and loadings. The high traffic and load areas should be considered for either extra support piles or piles driven deeper. To safely maintain a causeway pier over a long period it is necessary to run a settlement survey on a regular basis. This continuous check will indicate unequal settlement, which induces torsional loadings of the sections. To increase the accuracy of the survey, it should be scheduled during periods of little or no activity. If significant unequal settlements occur, the jacking system will be reinstalled, and the deck heights readjusted.

Table A-1. Pile Drive Depth Determinations

Section No.[a]	Actual Pile Length (ft)	Actual Height of Deck Above MLW (ft)	Actual Depth Soundings at MLW[b] (ft)	Min/Max Water Depths Allowable at MLW (ft)	Actual Drive Depths (ft)	Pile Length (ft) Above Deck – Before Drive	After Drive but Before Elevate	After Elevate
10B	26	7	-2	0/4	10	23	13	6
10S	27	7	-1	0/5	10	23	13	6
9B	25	9	0	0/6	10	25	13	3
9S	31	11	0	0/6	10	27	17	5
8B	32	12	0	0/5	10	27	17	5
8S	37	14	1	0/7	11	31	20	6
7B	39	15	3	0/10	11	32	21	5
7S	41	17	5	0/10	10	32	22	4
6B	47	18	7	1/13	10	34	24	7
6S	50	20	10	5/17	11	37	26	4
2B	50	20	11	5/17	10	36	26	4
2S	52	20	13	7/19	10	36	26	4
4B	50	20	11	5/17	10	36	26	4
4S	53	20	13	7/19	10	36	26	6
1B	52	20	13	6/18	10	35	25	4
1S	59	20	16	14/26	12	40	26	6
3B	52	20	13	6/18	10	35	25	4
3S	59	20	15	14/26	13	41	26	6
5B	59	20	15	14/26	–	41	–	–
5S	60	20	18	15/27	–	39	–	–

[a]B = Beach End; S - Sea End. See Figure A-2 for location of sections.

[b]Taken at time of beachings.

Appendix B

ENGINEERING ANALYSIS AND HUMAN FACTORS STUDY OF PIER CONSTRUCTION AND RETRIEVAL

The activities are depicted as observed during the Phase II Coronado exercise. The activity analysis describes the problem areas associated with personnel interaction with equipment. The engineering analysis describes the problem areas associated with equipment performance and interaction of equipment with equipment and personnel. Methods and hardware that would improve the activity are included as recommendations. Personnel requirements in terms of the described and recommended activity are tabulated.

PIER CONSTRUCTION

The ten-section floating causeway was momentum-beached using two warping tugs positioned alongside Section 5 and Section 1 (Figure B-1). The truck crane was prepositioned on Section 2 and the beach ramps on Section 8. The piles were dropped from Sections 5, 3, 1, 10, and 9 and driven using the diesel pile hammer and the truck crane. The beach ramps were positioned using the truck crane. The jacks were positioned on the previously driven piles of Section 9, and the piles of Section 8 were driven. Sections 9 and 10 were lifted into position, and the piles were driven through Section 7. This process was continued until the nine sections composing the elevated causeway were lifted into position (Table B-1).

Activity: CAUSEWAY BEACHING

Description: The causeway was beached at a predetermined location by two warping tugs and then held in position by two bulldozers until several piles were dropped.

Four men were stationed on the bow of the first causeway section as it was beached. One man supervised the other three personnel – a radio communicator and two line handlers. Once the causeway was beached, the line handlers attached a cable from each of the two bulldozers to the seaward end of the first causeway section. A fifth man stationed on the beach directed the operation from that position.

The bulldozers then took up the slack in the cables to anchor the causeway. A survey party, which consisted of two men, took soundings at various positions along the causeway to verify suitable positions for the different length piles. The causeway was not pulled onto the beach. Several piles were then dropped to anchor the floating causeway.

Activity Analysis: The piles were dropped before the causeway had been sufficiently pulled up onto the beach by the bulldozers. This situation made it necessary to repeatedly replace sand around and in front of the beach ramp of the beached causeway section. It appears that the inadequate beaching problem was the result of a lack of communication between the dozer operators and personnel dropping the piles. Premature pile dropping could have much more serious consequences, e.g., need to push the causeway section off the beach if the beach site was found to be unsatisfactory, or if the possibility of causeway broaching existed.

Engineering Analysis: During the initial phases of beaching, the bulldozers are required to pull the causeway sections onto the beach as far as possible before the piles are dropped. Two TD-25s, weighing 75,000 pounds (34.0 Mg) each, can pull one causeway section completely onto the beach by exerting a force in excess of 50 tons (45.4 Mg). A properly beached causeway will not require an excessively long beach ramp and/or sand erosion preventive measures in the area of the beach ramp. In addition to properly beaching the causeway, the dozers assist in maintaining the causeway alignment prior to the dropping and driving of several pipe pilings. When the bulldozers are connected with wire rope to the causeway two or three sections from the beach, they can exert appreciable lateral forces to the causeway string to assist the warping tugs in preventing broaching of the causeway onto the beach. Several soundings must be taken along the causeway to verify suitable locations

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Activity Analysis: The piles were dropped before the causeway had been sufficiently pulled up onto the beach by the bulldozers. This situation made it necessary to repeatedly replace sand around and in front of the beach ramp of the beached causeway section. It appears that the inadequate beaching problem was the result of a lack of communication between the dozer operators and personnel dropping the piles. Premature pile dropping could have much more serious consequences, e.g., need to push the causeway section off the beach if the beach site was found to be unsatisfactory, or if the possibility of causeway broaching existed.

Engineering Analysis: During the initial phases of beaching, the bulldozers are required to pull the causeway sections onto the beach as far as possible before the piles are dropped. Two TD-25s, weighing 75,000 pounds (34.0 Mg) each, can pull one causeway section completely onto the beach by exerting a force in excess of 50 tons (45.4 Mg). A properly beached causeway will not require an excessively long beach ramp and/or sand erosion preventive measures in the area of the beach ramp. In addition to properly beaching the causeway, the dozers assist in maintaining the causeway alignment prior to the dropping and driving of several pipe pilings. When the bulldozers are connected with wire rope to the causeway two or three sections from the beach, they can exert appreciable lateral forces to the causeway string to assist the warping tugs in preventing broaching of the causeway onto the beach. Several soundings must be taken along the causeway to verify suitable locations

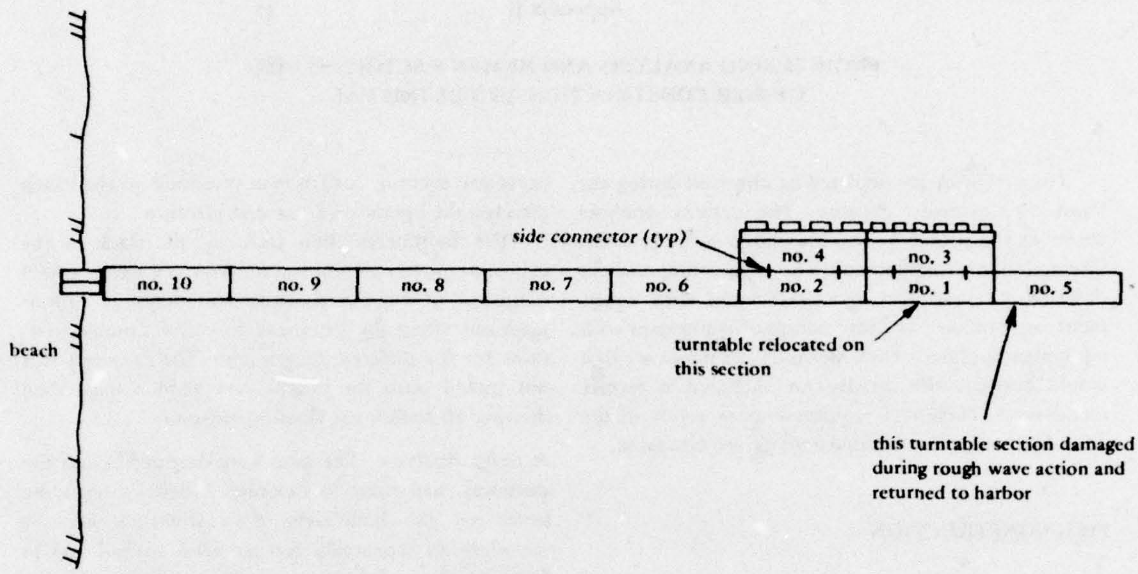


Figure B-1. Section location of beached causeway at Coronado.

for the various lengths of piles prior to dropping and driving them. The pile length and location determinations are discussed in Appendix A. After the first piles are driven through the seaward and beach end of the causeway, the broaching wires are no longer required.

Recommendations: It is recommended that adequate communications among the beaching officer, the sounding/survey party, bulldozer operators, the warping tug captain, and pile-dropping personnel be maintained. The causeway should be pulled onto the beach as far as possible. Proper causeway beaching will minimize sand erosion problems at the beach ramp, which are most severe during the occurrence of a high tide/heavy surf.

Personnel:

Type of Personnel	Observed		Recommended	
	No.	Rate	No.	Rate
Supervisor	2	BM	1	EOC
Radio Operators	3	RM	3	RM
Line Handlers	2	SR	5	SR
Sounding Party	2	EA	3	EA
Leadman (causeway section)	–	–	1	SN

Table B-1. Activity Sequence for Pier Construction

Activity Sequence	Section Number[a]			Remarks
	Pile Driving	Jack Positioning	Disconnection, Elevating, and Reconnection	
1	1,3,5,9,10[a]			Beach ramps positioned using truck crane.
2		9		
3	7,8		9,10	Truck crane positioned on floating sections for pile driving and jack positioning. Hydraulic crane positioned on elevated sections for jack removal.
4		8		
5	6		8	
6		7		
7	2		7	
8		6		
9	4		6	
10		2		Dozer (TD-25) positioned on elevated sections during reconnection of sections.
11			2	
12		1		
13			1	Section No. 1 lifted with truck crane and pile hammer.
14		4		Section No. 5 removed because of damage.
15			4	
16		3		
17			3	
18				Jacks and cranes transferred to beach.

[a] Refer to Figure B-1 for section location.

Activity: **POSITIONING PILES AFTER BEACHING** (Figure B-2)

Description: A cable sling was attached near one end of the pile and then hooked to the crane cable by two line handlers. A third man then signalled the crane operator to lift the pile from the deck and position it over the spudwell. Four or more men usually attempted to physically guide and position the pile over the spudwell to reduce pendulations. Once the pile had been properly positioned over the spudwell, the crane operator was signalled to lower the pile. After the pile was dropped, the crane cable was released from the top of the pile by a man on deck pulling on a cable-sling release line.

Activity Analysis: The ability of the tagline handlers to significantly move or restrain movement of the

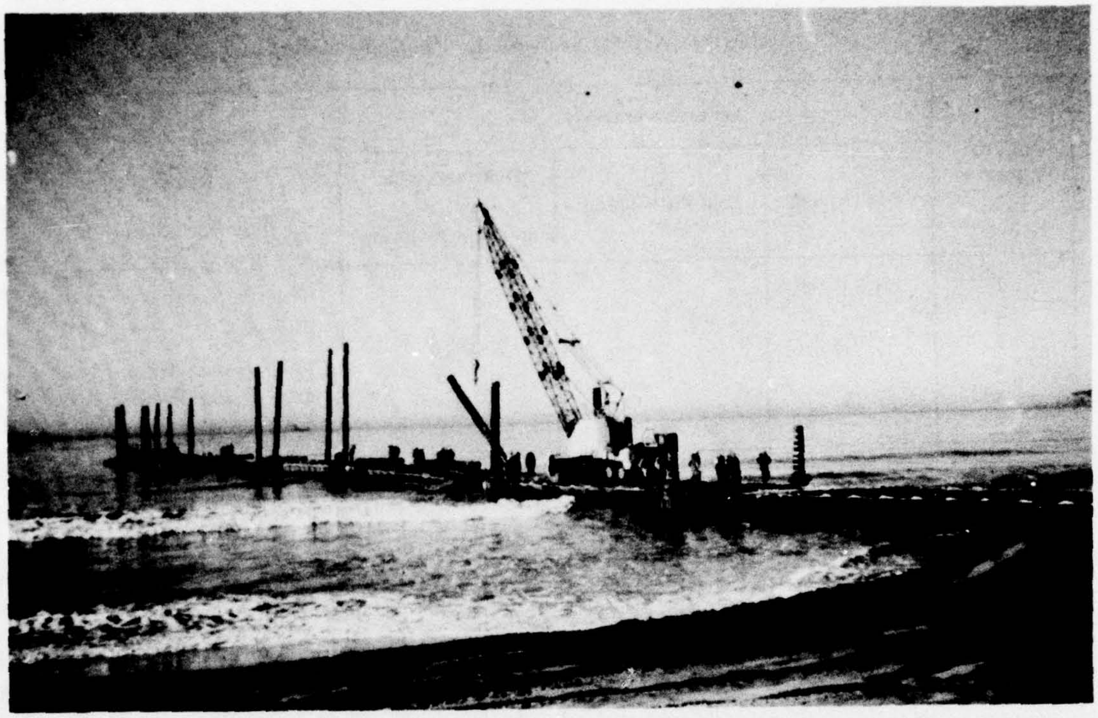


Figure B-2. Positioning piles with truck crane after beaching.

piles is questionable. The location of the handlers as the pile approached the spudwell was almost always between the crane operator and the spudwell, thus blocking the crane operator's view of the bottom of the pile and the spudwell. It is conceivable that the tagline handlers are of some help in limiting the pendulation of the pile during moderate sea states. The task of attempting to manhandle a 3-ton (3.1-Mg) pile at the spudwell location is hazardous.

Engineering Analysis: Pile taglines can be used if an advantage can be obtained by taking several wraps of line around a nearby bitt or shackle attached to the causeway. The tagline should be on the opposite side of the crane to keep the pile from pendulating toward the crane boom. Mechanisms for gaining tagline advantage, such as special shackles or other hardware that can be attached to the causeway angles, should be developed.

Recommendations: It is recommended that devices and/or methods be developed that will enable the tagline handlers to apply greater force to the pile, particularly in the plane of the crane boom axis. The tagline handlers should stay clear of the spudwell and the pile during pile insertion. If the present method is to be retained, the function of the tagline handlers should be to limit pile pendulation as best they can and leave positioning of the pile up to the crane operator. The tagline handlers should stay clear of the crane operator's line of sight to the spudwell. Consideration should be given to transporting the piles positioned vertically in the spudwells.

Personnel: Two tagline handlers, two riggers, a supervisor/signalman, and a crane operator are considered adequate to perform this activity. Tagline handlers should be provided with a mechanical advantage so that significant reductions in pile pendulation can be obtained while positioning over the spudwell. The riggers assist in rigging the pile for positioning.

Type of Personnel	Observed		Recommended	
	No.	Rate	No.	Rate
Crane Operator	1	EO2	1	EO2
Supervisor/Signalman	1	EO2	1	EO2
Tagline Handlers/ Riggers	4+	EO3	4	SN/SR*

*Require mechanical assistance.

Activity: **PREPOSITIONED PILES**

Description: Fourteen piles were transported to the beaching site in the vertical position within various spudwells and were maintained in this position by a combination of welding and pinning. Upon beaching the causeway, piles located on the beachward end and the seaward end of the causeway were dropped by cutting the gussets and/or the pins holding the piles in the vertical position in the spudwells. This was accomplished by two steelworkers using an oxy-acetylene cutting torch and tanks that had been positioned on the causeway prior to transport of the causeway to the beach site.

Activity Analysis: The process of dropping the piles was simple and straightforward. The only problem noted with this scheme was the failure of several welds during transit. This required shoring up some of the piles with wooden blocks driven into the space between the spudwell and pile.

The benefits of this technique are that the piles can be dropped more quickly following beaching of the causeway than if the piles had to be inserted into the spudwells and dropped using the truck crane. Also, it is less hazardous for personnel to position the piles vertically in the spudwells at sea prior to beaching than to position and insert the piles into the spudwells after the causeway is in the surf zone. Piles lashed horizontally on the deck require constant attention to make sure the lashings remain tight. The accidental or intentional release of the lashings during pile positioning is hazardous to the operating personnel.

Engineering Analysis: Beaching the causeway with the piles positioned upright in the spudwells is beneficial for the following reasons: (1) the 3x15 NL pontoon sections are narrow [21 feet (6.4 m) wide]; therefore, the piles set upright in the spudwells rather than horizontal on the deck take up less space, leaving more room for the cranes and other equipment. (2) It is easier to secure a pile upright in a spudwell rather than horizontally on deck; less lashing gear is required. (3) Piles positioned upright at sea do not have to be inserted into the spudwells when the causeway is exhibiting maximum wave-induced motion within the surf zone. The piling can be set upright into the spudwells at sea, where the causeway string can be oriented alongside a ship or into the predominant waves such that causeway motion is minimized.* (4) The piling can be dropped through the spudwells of a beached causeway without crane assistance. Therefore, the crane does not have to be taken from its pile-driving duty to handle and position the piles. (5) Four piles could be dropped and driven in less than 1 hour using this method.

The upright piles do not appreciably affect causeway stability. A 62-ton (56.3-Mg) NL causeway section with four internal spudwells and no crane on board has a metacentric height of 30 feet (9.14 m). The metacentric height is decreased to 9.7 feet (3.0 m) with the addition of a truck crane weighing 55 tons (49.9 Mg) and four pipe piles weighing 6.4 tons (6 Mg) placed horizontally on the deck. The piles installed upright in the spudwells of a section carrying a truck crane decrease the metacentric height from 9.7 feet (3.0 m) to 9 feet (2.8 m). The roll stability of the section is decreased only 7.2%. A section carrying piles upright in the spudwells and no crane has a metacentric height of 15.7 feet (4.8 m).

An NL section weighing 62 tons (56.3 Mg) and carrying a 55-ton (49.9-Mg) crane is quite stable with a metacentric height of 9.7 feet (3.0 m). Also, NL causeway sections are end-connected before installation of equipment; thus, the overall stability of the causeway is much greater than that indicated above where only one section is considered.

The best mechanism for holding the pile upright in the spudwell during transit was found to be a pinning arrangement. Tack welding the pile to the spudwell was found to be too rigid a connection, resulting in many broken welds and continual maintenance. The pinning arrangement, whereby small, 2-1/4-inch (5.7-cm) holes are burned in the pile and

*It is assumed that the causeway sections would be launched and end-connected at sea, after which piles, cranes, and miscellaneous pier construction gear would be placed on them.

2-inch by 36-inch (5.1-cm by 91.4-cm) round pins inserted, was most satisfactory. In actuality, the pinning holes can be burned in the piles during ship transit, then the pins can be easily installed during pile positioning at sea. The pins are inserted completely through the pile (one pin each pile) and rest on the top plate of the spudwell. The pinned joint allows the pile freedom of movement within the clearances of the pile and spudwell during transit. The pinned piling scheme requires the external spudwells to be positively connected to the causeway. The current bolted connection can work loose over a sufficient period of time; this problem will be solved with a guillotine mechanism. External spudwells will also be considerably easier to install with the new connection. In most cases 5 feet (1.5 m) of piling extending below the bottom of the pontoons is sufficient for this method of pile handling. The first few beach end sections should have no piling showing below the pontoon structure to prevent grounding of the piling during beaching.

Recommendations: The positioning of piles vertically at sea is recommended so that the crane can be used to drive piles on a continuous basis after the causeway is beached. It is recommended that pile-positioning methods at sea be investigated.

It is recommended that the piles be secured in the spudwells by the pinning method. This method is structurally better than tack welding, offers savings in the time necessary to vertically position the piles in the spudwells, and reduces the time required to drop the piles after the causeway has been beached. It is also recommended that the external-spudwell-to-causeway connection be modified to insure the spudwells will support the piling pinned vertically for an indefinite period of time without separating from the causeway sections.

Personnel: Although two steelworkers (welders) could cut the pile-supporting pins, a minimum of four steelworkers is recommended. More piles can be dropped simultaneously if additional steelworkers are provided. A crane operator, a signalman, and tagline handlers/riggers are required to position the piles at sea. The riggers insert the pins and prepare the piles for positioning. The following personnel are recommended for the prepositioned pile method:

Type of Personnel	Required	
	No.	Rate
Crane Operator	1	EO2
Supervisor/Signalman	1	EO2
Tagline Handlers/Riggers	4	SN/SR
Steelworkers	4	SW3/SWCN

Activity: **PILE DRIVING** (Figure B-3)

Description: Pile-driving operations began by attaching the crane hook and auxiliary hook to the leads and tripping mechanisms of the pile hammer that was horizontally positioned on the deck of a causeway section. The hammer was then lifted, guided into position over the pile, and inserted. It was then activated, and the pile was driven into the ocean floor. The hammer was then removed from the pile and either lowered to the deck of the causeway section or transported to the next pile to be driven. This sequence of tasks took approximately 10 minutes.

In terms of personnel, a line handler attached the crane cables to the leads and tripping mechanism of the hammer. The hammer was guided into position by line handlers manning four cables attached to the hammer. Up to eight men were used on the largest of the four lines, and occasionally steelworkers helped with the lines. Once the hammer was inserted into the pile, the tripping mechanism was pulled as the crane lifted and dropped the piston and the hammer started. A line handler stood by to adjust the throttle through a hydraulic line connected to the fuel pump.

Another line connected to the fuel pump cam is used to stop the hammer after the pile has been driven to its proper depth. The hammer is removed in the reverse manner in which it is installed.

Activity Analysis: The ability of the line handlers to significantly affect the position or reduce the pendulation of the hammer is doubtful due to its weight. The forces necessary to appreciably reduce the motion or to move a pendulum as heavy as the hammer used in this operation are beyond those that can be exerted by the tagline handlers without a mechanical advantage. This became apparent in several instances when up to seven handlers on one

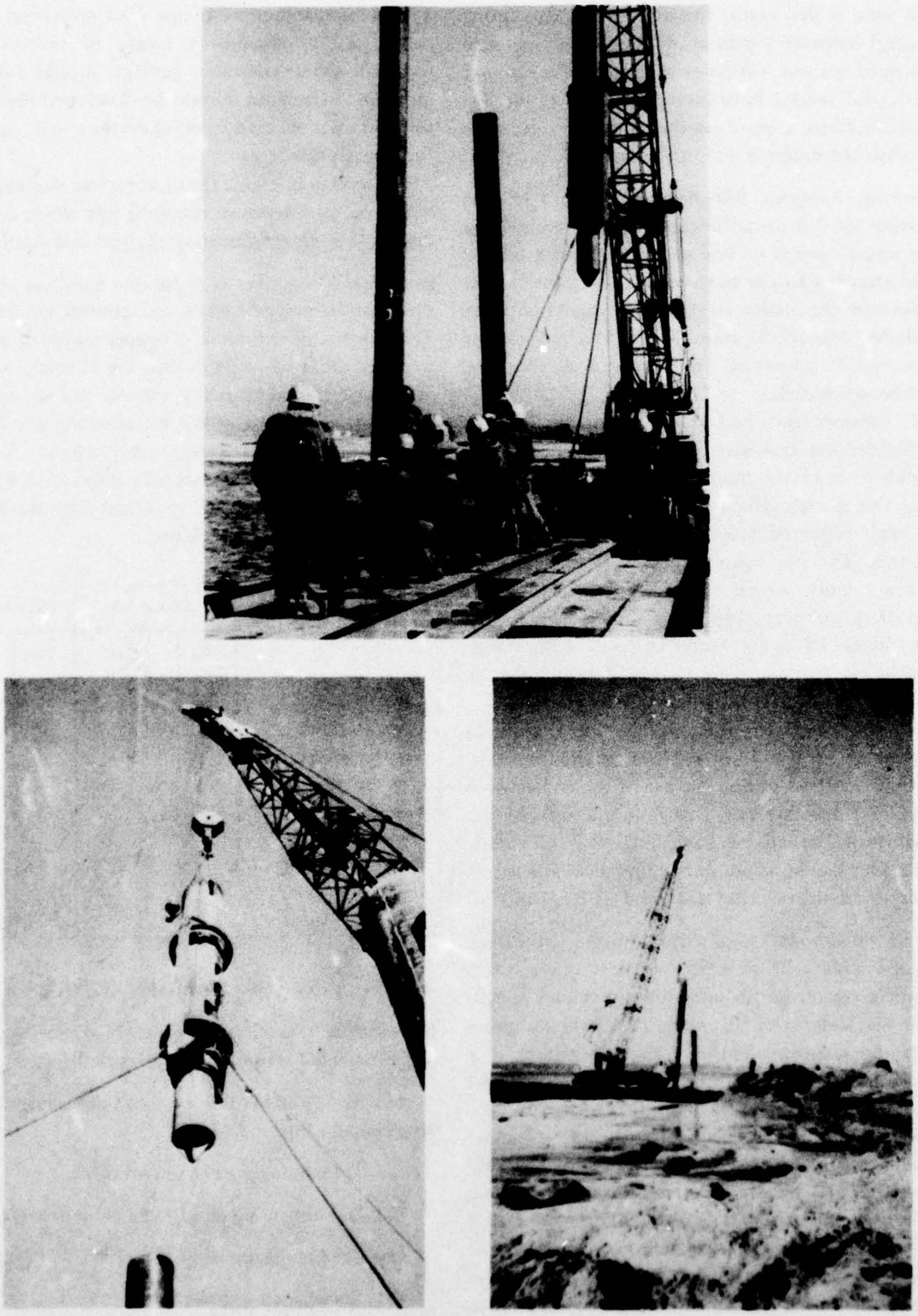


Figure B-3. Driving pile with DE-30 diesel pile hammer.

tagline were pulled across the deck while attempting to control hammer pendulation. Difficulty was also experienced on one occasion in getting the hammer to start, and several hours were lost as a result. On another occasion, a brace on the hammer leads broke loose while the hammer was operating.

Engineering Analysis: Pile hammer taglines can be effectively used if an advantage can be obtained by taking several wraps of line around a nearby bitt or shackle attached to the causeway. The tagline should be opposite the crane to keep the hammer from pendulating toward the crane boom. Mechanisms for gaining tagline advantage, such as special shackles, should be developed.

Pile hammer leads had to be continually repaired. The lead failures consisted of cracks in the areas of the guide-to-head weldment and in weldments connecting the guides. The failures were due to excessively high repeated stresses in the areas of these weldments. The pile leads should not be welded or otherwise rigidly attached directly to the hammer drivehead or cylinder. The leads should be attached to the drivehead and cylinder through a slip-flange system of the hammer. The tip guide should also be attached to this free-floating hammer lead system.

The piles used for this exercise were driven a maximum of 15 feet (4.6 m). The maximum settlement that occurred during the use of the constructed pier was 1-1/2 inches (3.8 cm). The pile drive depth determinations should be based on a site soil survey analysis, pier loadings, and maximum allowable causeway section deflections, as discussed in Appendix A.

Recommendations: A device/method should be developed that will give the tagline operators a mechanical advantage for controlling hammer pendulations, particularly in the plane of the crane boom axis. If the present method is to be retained, it is recommended that the number of tagline handlers be reduced to the minimum required to orient the hammer around its longitudinal axis and to handle the hammer stop line. No more than four men should be necessary to handle the two taglines and the throttle and stop lines. It is also recommended that some method of checking out the operation of the hammer be devised prior to its transport to the beaching location. A free-floating hammer lead system that would provide ample hammer stability and alignment and eliminate lead structural failures should be developed. A means of protecting the hammer from saltwater damage should be implemented. A checklist should be developed that assures the hammer is ready for operation, e.g., adequate fuel, inspection, etc.

It is recommended that a complete site soil survey be made to determine required pile drive depths as discussed in the engineering analysis and Appendix A.

Personnel: The five to eight line handlers that man the pile hammer taglines are considered excessive. Three or no more than four riggers should be required to man the two taglines and the throttle and stop lines since the additional personnel did not appear to have any significant effect on reducing pile hammer pendulation or its positioning. Fewer personnel would be exposed to hazards associated with this activity, i.e., being struck or dragged by the hammer as it is moved or is pendulating.

Type of Personnel	Observed		Recommended	
	No.	Rate	No.	Rate
Supervisor	–	–	1	EOC
Crane Operator	1	EO2	1	EO2
Supervisor/Signalman	1	EO2	1	EO2
Line Handlers	5-8	EO3/SW3	–	–
Throttle Control Operator	1	–	1	EO3
Stop Line Handler	1	–	1	EO3
Hammer Tagline Handlers	–	–	2	SN/SR

Activity: **LIFT SYSTEM MOBILIZATION**

Description: The lift system mobilization operation was subdivided into nine activities as follows:

(1) Transporting pile caps and mounting them on the pile cap support fixture

(2) Transporting jack control console

(3) Disconnecting jacks from causeway section

(4) Gimbal disassembly

(5) Transporting gimbal plates

(6) Gimbal assembly

(7) Transporting and rigging of jack

(8) Transporting jack/pile cap and mounting on pile

(9) Connecting jacks to causeway section

Once the load had been transferred from the jack/chain/gimbal assembly to the turnbuckle pile cap assembly, the jack and gimbal assembly were ready to be released and prepared for transport to the next pile. The first step was to disconnect the removable chain links or shackles from the inboard and outboard gimbal sections. The jack control console was moved from the beach to a causeway section using the hydraulic crane in preparation for causeway elevation operations. The hydraulic crane was backed out onto the causeway, while one man stabilized the console with a line attached to the unit. After a section had been elevated, the console was moved to the seaward end of the elevated section by the hydraulic crane. From this location the hydraulic lines could reach the most distant jacks on the next floating section to be elevated. Also, the control console operator was able to observe jack operation and to communicate with the riggers stationed at the base of each pile on the section to be elevated. The tasks associated with console transport included attaching cables from the bottom of the console to the hydraulic crane hook, and lift and transport of the console to its new location. Three to four men handled the hydraulic lines connected between the jacks and the console during console transport. The console operator supervised the operation and gave signals to the hydraulic crane operator.

After the detachable chain links/shackles had been removed from the inboard and outboard gimbal sections, the gimbal was removed from the pile by disassembling the four interlocking gimbal sections. Although this task was not always performed in the same sequence, it consisted of pulling the pins on the gimbal cross sections to release them. The gimbal sections (pivot plates) attached to the compensating rod were then disconnected by removing the pin going through the gimbal section and compensating rod padeye. Sections of welding rods used as cotter pins had to be removed prior to pin removal. Three and sometimes four riggers accomplished these tasks.

The gimbal plates were transported in a number of ways – one man carrying a single plate, two men carrying a plate, and two men carrying two plates. The truck crane was usually used to lower a number of gimbal plates from an elevated causeway section to the next floating section to be elevated.

The gimbal plates were then assembled around the pile of the floating section. The two pivot plates were assembled first, then the inboard, and finally the outboard plates were assembled and pinned. The gimbal assembly crew consisted of four men. Sometimes a man would have to position himself on the outboard side of the pile.

While the gimbal plates were being transferred, the jacks were released from the pile caps on the elevated section by pulling the locking pins. The jacks and new pile caps were then transported to the assembly area on the seaward end of the elevated section. The hydraulic crane was used for transporting the jacks, while a forklift transported the pile caps. Occasionally a pile cap was moved by hand by four men. The pile cap was manually lifted onto a cylindrical support fixture by four members of the jack crew, and the jack was then mounted onto the pile cap and support fixture using the hydraulic crane. Two or three men would help to physically guide the jack down onto the pile cap, while one man gave signals to the hydraulic crane operator. The jack and pile cap were then connected together. If not previously attached (first time only), the hydraulic lines were connected to the jack, and the lift chains were installed. Appropriate lengths of lift chains were pulled through the unlatched jack openings and over the idler wheels. This was usually performed by two men. Often the chain was recycled on both sides of the jack simultaneously by four men.

The chain-rigged jack and pile cap were then lifted into position onto the top of the pile on the next floating section to be elevated using the truck crane positioned on the floating section. Two lines attached to the ends of the chains were manned by tagline handlers during transport, and several additional men attended to the hydraulic lines. A man gave both verbal and hand signals to the crane operator during the jack-mounting operation. Once the jack and cap were properly positioned and seated atop the pile, a special hook release line was pulled to disconnect the crane hook from the jack. The jack lift chains were then attached to the inboard and outboard gimbal plates with either a removable chain link or shackle.

Transporting Pile Caps and Mounting on Fixture (Figure B-4)

Activity Analysis: The hydraulic crane and occasionally a rough terrain forklift were used to move the pile caps to the jack rigging location at the seaward end of the elevated section. No problems were noted in transporting the pile caps using either of these vehicles. The next task, that of lifting the pile caps from the deck and mounting them on the support fixture, was accomplished quickly by four men. The weight and shape of the pile cap make lifting and transporting it potentially hazardous to personnel.

Engineering Analysis: The pile cap as a piece of causeway temporary suspension hardware can be eliminated with the use of 20-inch (50.8-cm) OD pipe pile. The suspension system that can replace pile caps, turnbuckles, shackles, and chain is a pile-pinning arrangement.* Four 4-inch (10.2-cm) square steel pins, each approximately 3 feet (0.9 m) long, are inserted through the pipe pile (one for each pile) beneath the elevated causeway section. A pinning hole is burned through the pile above the deck of the section during the final stages of the elevating process. The section is then elevated past the pinning holes, and pins are inserted beneath the section from within the internal spudwells. For external spudwells, the pins could be inserted from personnel walkways attached to the spudwell.

Recommendations: Consideration should be given to providing a mechanical means of lifting, transporting, and mounting the pile cap adapter onto the support fixture to eliminate the possibility of injury to personnel. This method would probably take longer than the present manual method.

It is recommended that alternate methods of attaching the piles to the causeway section spudwells be investigated to eliminate the need for the temporary suspension system.

It is recommended that the pinned connection scheme be developed.

Personnel: Five people were required to perform this task – a hydraulic crane/forklift operator and four riggers. These requirements could be reduced to one signalman/rigger and the hydraulic crane operator by providing an alternate means of lifting and positioning the pile cap adapter onto its container fixture or by eliminating the need to lift the pile caps.

Method	Type of Personnel		
	Duty/Title	Rate	No.
Observed	Forklift/Hydraulic Crane Operator	EO3	1
	Riggers	SR	4
Proposed – Mechanical Assistance	Hydraulic Crane Operator	EO2	1
	Rigger/Signalman	SN/SR	1
Eliminate Pile Caps (Recommended)	–	–	–

Transporting Jack Control Console (Figure B-5)

Activity Analysis: No problems were noted in accomplishing console transport, and it does not appear that this task can or should be performed significantly faster. It is also felt that the crew involved in transporting the console could not be reduced without degrading the operation. Some potential for damage to the console and hydraulic lines was noted. Protruding components, such as hydraulic connectors, control levers, and latch indicator lights, could conceivably be damaged if other objects were to strike them. The hydraulic connectors are probably the most vulnerable; a protective cage could be provided, or the connectors could be recessed. The latter solution would probably entail more design and modification effort and would make the connectors less accessible when connecting the hydraulic lines. A definite possibility of crossing or otherwise entangling the hydraulic lines exists that could necessitate their disconnection from the power control unit to disentangle them. The hydraulic crane further aggravates this situation by being in the immediate area. The hydraulic crane could be relieved for other duties if the console could be moved under its own power. By removing the hydraulic crane from this area, the space can be maximized for power unit and hydraulic hose movement.

*The temporary suspension system would be eliminated also with the mechanical pile-to-causeway connection under development; it is discussed in Volume III.

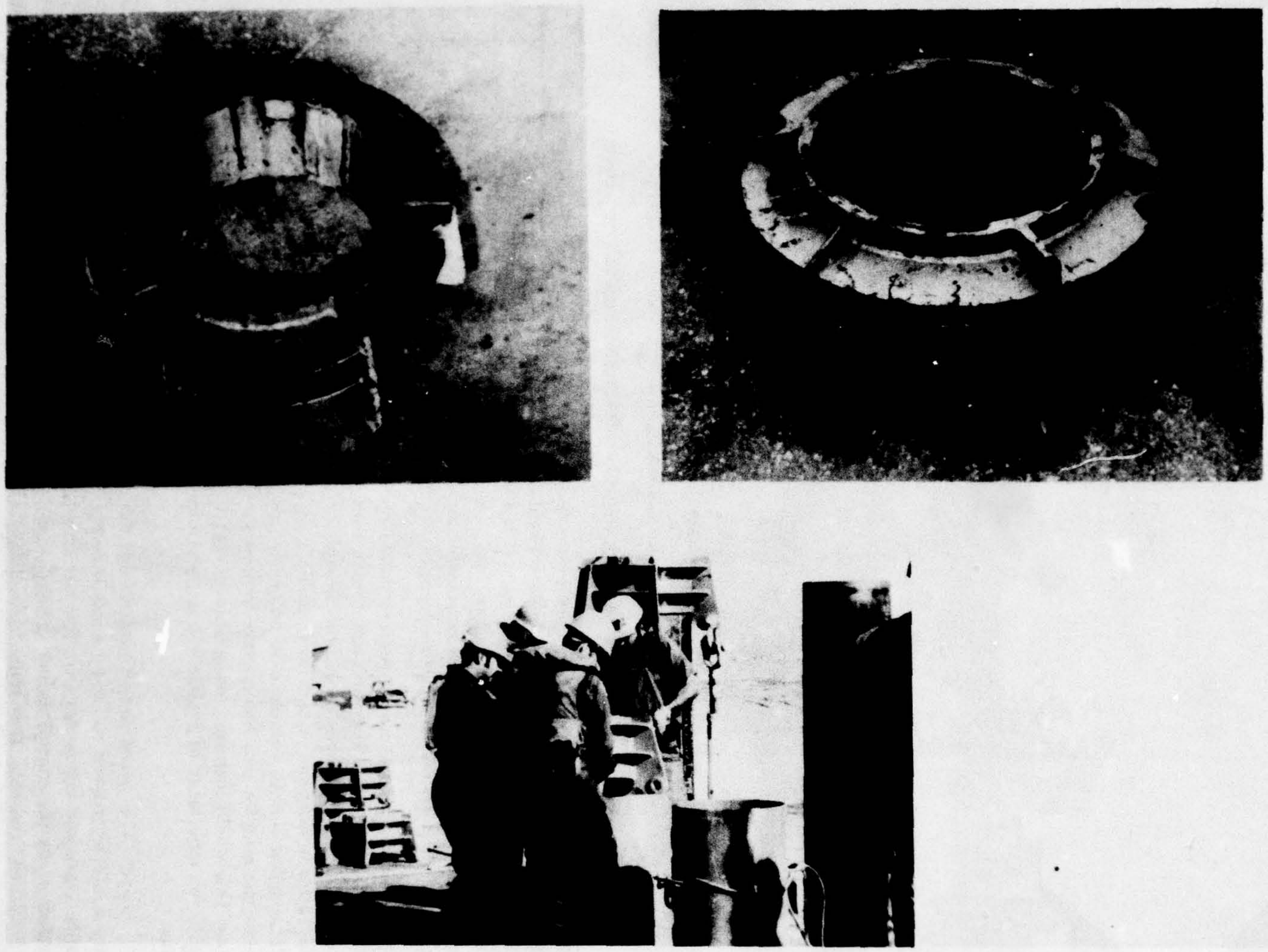


Figure B-4. Transporting pile caps and mounting on support fixture.

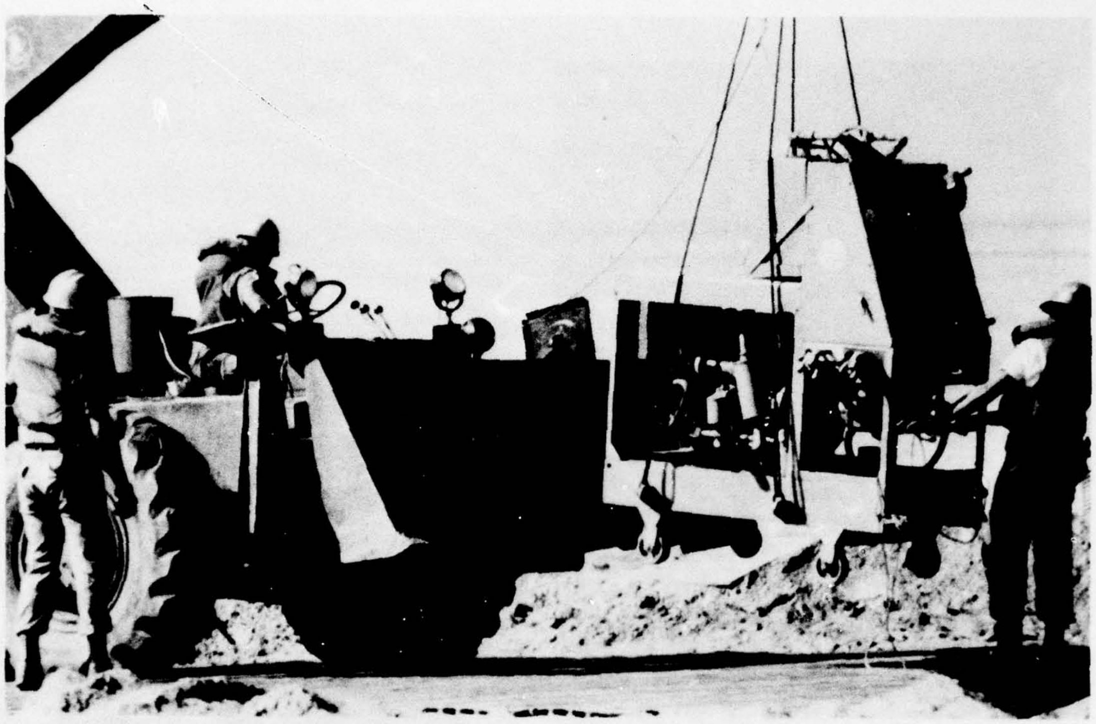


Figure B-5. Transporting jack control console from beach to first section.

Engineering Analysis: The jack control console can be designed such that it can be rolled forward under its own power. Pneumatic tires that will not interfere with pontoon deck appendages could be used. The hydraulic crane would then be available for other duties of jack transfer and jack recycling.

Recommendations: A protective cage should be provided to protect the hydraulic connectors from physical damage. A fixed procedure should be developed for moving and placing the hydraulic lines. A self-propelled control console is recommended to eliminate the need for a hydraulic crane to move the console. This would increase considerably the space available for movement of hydraulic hoses and the console.

Personnel: The seven men involved in this activity could be reduced to six by eliminating the hydraulic crane and tagline handler. This task could be performed by the control console operator and a self-propelled console. The four hydraulic line handlers would still be required.

Method	Type of Personnel		
	Duty/Title	Rate	No.
Observed	Supervisor/Signalman	BM2	1
	Hydraulic Crane Operator	EO3	1
	Hydraulic Line Handlers	SR	4
	Tagline Handler	SN	1
Recommended*	Console Operator/ Supervisor	EO2	1
	Signalman	EO3	1
	Hydraulic Line Handlers	SN/SR	4

*Requires a self-propelled control console.

Disconnecting Jacks From Causeway Section

Activity Analysis: Although no actual problems were noted in accomplishing this activity, a potential exists for personnel injury and loss of hardware.

Removal of the detachable link/shackle on the outboard gimbal section requires the rigger to position himself close to the edge of the causeway section. If a safety harness is not used, he must support himself with one hand while disconnecting the detachable link/shackle or be supported by another rigger in order to use both hands. In addition to possibly losing his footing and falling overboard, the detachable link/shackle could also be lost over the side or through the spudwell.

Engineering Analysis: Portable personnel walkways that can be attached to the external spudwells can be developed. This would appreciably reduce the hazards for personnel working around the pile while standing on the spudwell. Improved methods for attaching the lift chain to the gimbal should be investigated.

Recommendations: It is recommended that the present number of personnel be retained. When removing the shackle from the outboard gimbal section, the rigger should always use a safety harness. It is recommended that a detachable personnel walkway be developed for the external spudwells. It is recommended that gimbal assemblies be modified to incorporate improved connecting components, and that more effective assembly methods evolve from the improved hardware.

Personnel: Four riggers (SN/SR) are considered adequate for performing this task. Two jacks could be disconnected simultaneously with two riggers at each of the two jacks.

Gimbal Disassembly

Activity Analysis: This activity requires riggers to work on the outboard portion of the external spudwells to release the locking pins and to lift and transport the heavy gimbal cross section. There are several ways of reducing this hazard and the time necessary to disassemble (and subsequently reassemble) the gimbals. One way is to eliminate the use of steel gimbals. An engineering analysis would have to be performed to determine the technical feasibility of this approach. This and other possible solutions are presented in the gimbal assembly subtask of the jack rigging activity. The welding rod "cotter pins" were sometimes difficult to remove; pliers were sometimes required.

Engineering Analysis: Portable personnel walkways to be attached to the external spudwells can be developed. This would appreciably reduce the hazards for personnel working around the pile while standing on the spudwell. The arrangement for connecting the gimbal assemblies to the lift padeyes can be improved (see Engineering Analysis for Gimbal Assembly of Lift System Mobilization).

Recommendations: See Recommendations given for Transporting Gimbal Plates and Gimbal Assembly of Lift System Mobilization.

Personnel: Personnel are adequate for the current method. Four riggers (SN/SR) are preferred over three for safety reasons.

Transporting Gimbal Plates

Activity Analysis: The disassembled gimbal plates are transported by hand on both the elevated and floating causeway sections. The truck crane, which is positioned on the floating sections, is used to lower the plates from one section to the other. The transport cycle is: hand carry – rig for crane – crane lift and lower – hand carry.

Engineering Analysis: The steel gimbal assemblies currently used are close to being 100% mechanically effective. The problems associated with handling cannot be resolved easily because of structural requirements that stipulate the physical size, weight, and geometry of this equipment. Alternatives to steel gimbal assemblies are possible, but they may not be effective. Modifications to the currently used steel gimbal assemblies that will decrease handling problems should be investigated.

Recommendations: It is recommended that the gimbals be modified such that handling problems can be minimized without sacrificing structural integrity and mechanical effectiveness.

Personnel: Four riggers were usually involved in transporting the gimbal plates on the elevated causeway section to a temporary transfer point. The plates were then tied together, lifted, and transported to the floating section using the truck crane. Four riggers on

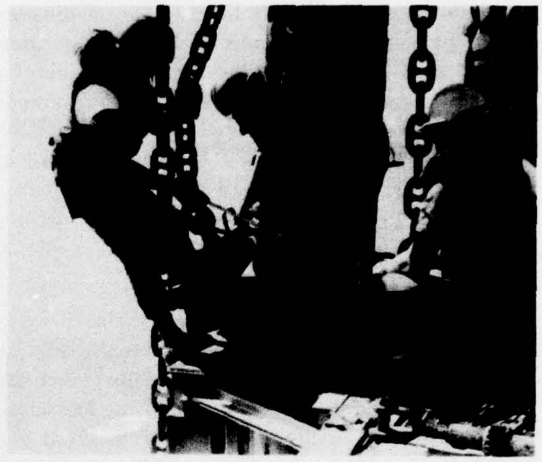


Figure B-6. Assembling gimbal.

the floating section then transported the plates to the spudwells for assembly. With the present method, eight SW/SR riggers (four on each causeway section), an EO3 signalman, and an EO2 truck crane operator are required. Two riggers should transport only one gimbal plate at a time.

Gimbal Assembly (Figure B-6)

Activity Analysis: The procedure of assembling or disassembling the gimbals requires four men, two of which must lean out around the pile or even climb out around the pile to maneuver the heavy gimbal sections into position. The awkward position of the men and the weight of the gimbal sections make this task hazardous to personnel and increase the likelihood of loss of equipment and personnel over the side, particularly when working on a floating causeway section with external spudwells.

Engineering Analysis: Portable personnel walkways that can be attached to the external spudwells can be developed. This would appreciably reduce the hazards for personnel working around the pile while standing on the spudwell.

The padeye pin connection arrangement for the gimbal compensator can be improved. A pin having a flange on one end should be used. The pin would be held in place by its flange on one end and a welding rod inserted through slots in the compensator padeye on the other end.

Recommendations: To avoid the problem of attaching the gimbals, it is recommended that an alternative to the use of gimbals be investigated. If this is not feasible, a stand should be provided for assembling the outboard gimbal sections on the external spudwells. It is recommended that the pin connection arrangement between gimbal and compensator padeyes be modified as indicated in the engineering analysis.

Personnel: While three riggers could accomplish the task, it is recommended that the present crew of four SN/SR riggers be retained. Also, a supervisor (EOC) should be added.

Transporting and Rigging of Jack (Figures B-7, B-8)

Activity Analysis: This activity required coordinated actions among the hydraulic crane operator, two to three rigger/hydraulic line handlers, and the jack control unit operator/supervisor. No problems were noted in the accomplishment of this activity; however, a definite possibility of snagging the hydraulic lines or the chains on the deck exists during jack transport. The placement of the jack onto the pile cap by the hydraulic crane operator and securing the pile cap to the jack were performed satisfactorily; no problems were observed.

The recycling of the chains to the proper length for the next pile was performed by three men -- two men pulling the chains, and the jack power unit operator to release and engage the chain latches as required. The length of chain required for the next pile was determined on the floating sections by using a long, lightweight measuring rod to estimate the pile height above the deck of the floating section. A close estimate of this length is necessary to reduce the time required to take up the slack in the lift chain after it is attached to the gimbal of a floating section and, more importantly, to assure that the chain is sufficiently long to preclude tension on the chain during the connection of the chain to the gimbal assembly.

Engineering Analysis: Pile caps can be eliminated if 20-inch (50.8-cm) OD pipe piles are used (see Engineering Analysis of Transporting Pile Caps and Mounting on Fixture Activity). The jacks would have to be installed in some type of canister for recycling, however, so that other jacks could be disconnected and removed without delay.

Chain links can be marked every 5 feet (1.5 m) with a durable marking material.

The most satisfactory method for estimating the required length of lift chain for recycling is one whereby the distance from the floating causeway section deck at its lowest position of heave motion to the top of each of the four corner piles is determined by counting the number of painted rings from the top of each pile. The rings are painted at 5-foot (1.5-m) intervals. This measurement is not affected by tidal variations, and it can take into account allowances for free chain as required to safely make the gimbal/chain connection.

Recommendations: The ring counting method of determining the required length of jack chains should be implemented. The chains should be clearly marked at 5-foot (1.5-m) intervals with durable paint. Each pile would also be marked at 5-foot (1.5-m) intervals prior to being positioned. The present method of jack recycling should be retained.

Personnel: The observed number of personnel is considered adequate:

Type of Personnel	Rate	No.
Hydraulic Crane Operator	EO2	1
Jack Control Console Operator/Supervisor	EO2	1
Riggers	SN/SR	4

Transporting Jack/Pile Cap and Mounting on Pile (Figure B-9)

Activity Analysis: The transfer of the jack requires two truck crane operators and a crew of men on both the elevated causeway section and the floating section to be elevated. The elevated section crew consists of two to three people who hook the jack and clear the chains and hydraulic lines. The floating section crew consists of four people – two tagline handlers, one crane hook release line handler, and one man to clear the hydraulic lines.

Problems with the transfer of jacks stem from the possibility of the chains snagging on the deck and spudwells and also from the relative motion between the elevated and floating causeway sections. If the chains become snagged on the elevated causeway while the jack is being lifted by the crane on the pitching lower causeway, extreme stresses will be applied to the crane and the part being lifted. This situation is very dangerous and could result in the loss of a jack assembly and possible personnel injury.

The jack lift chains also have a tendency to snag in the floating causeway section spudwells once the jacks are mounted on the piling prior to being connected to the gimbal assemblies. This snagging can be very hazardous because of the vertical movement of the floating sections in the surf. The jacks could be pulled from the top of a piling if a lift chain became snagged in a spudwell attached to a heaving causeway section.

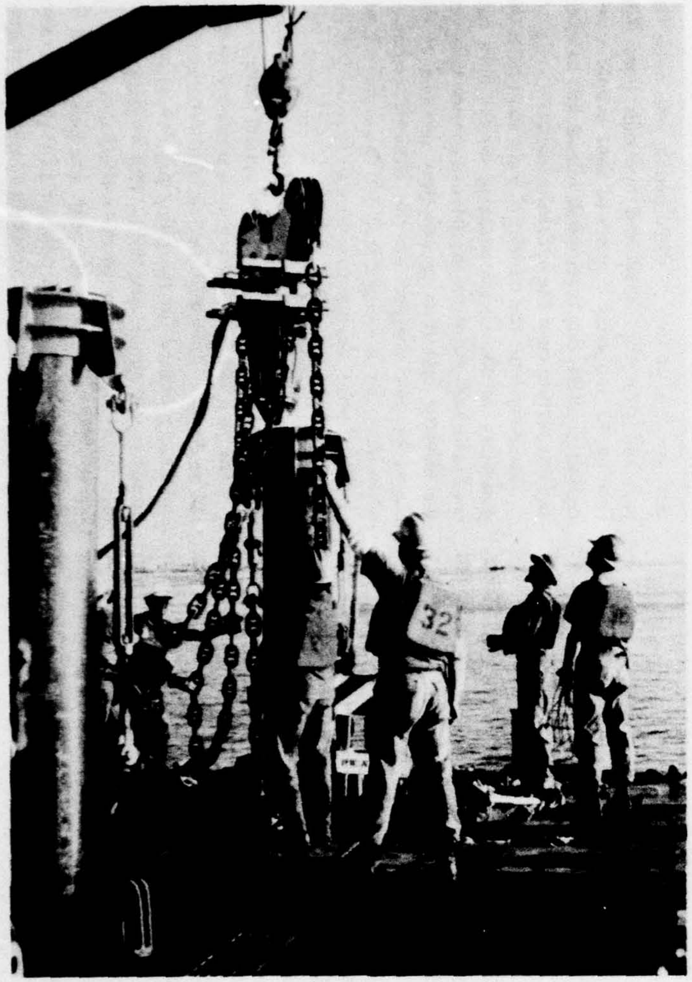


Figure B-7. Transporting jack with hydraulic crane.

Figure B-8. Rigging of jack lift chain prior to placement of jack on pile.

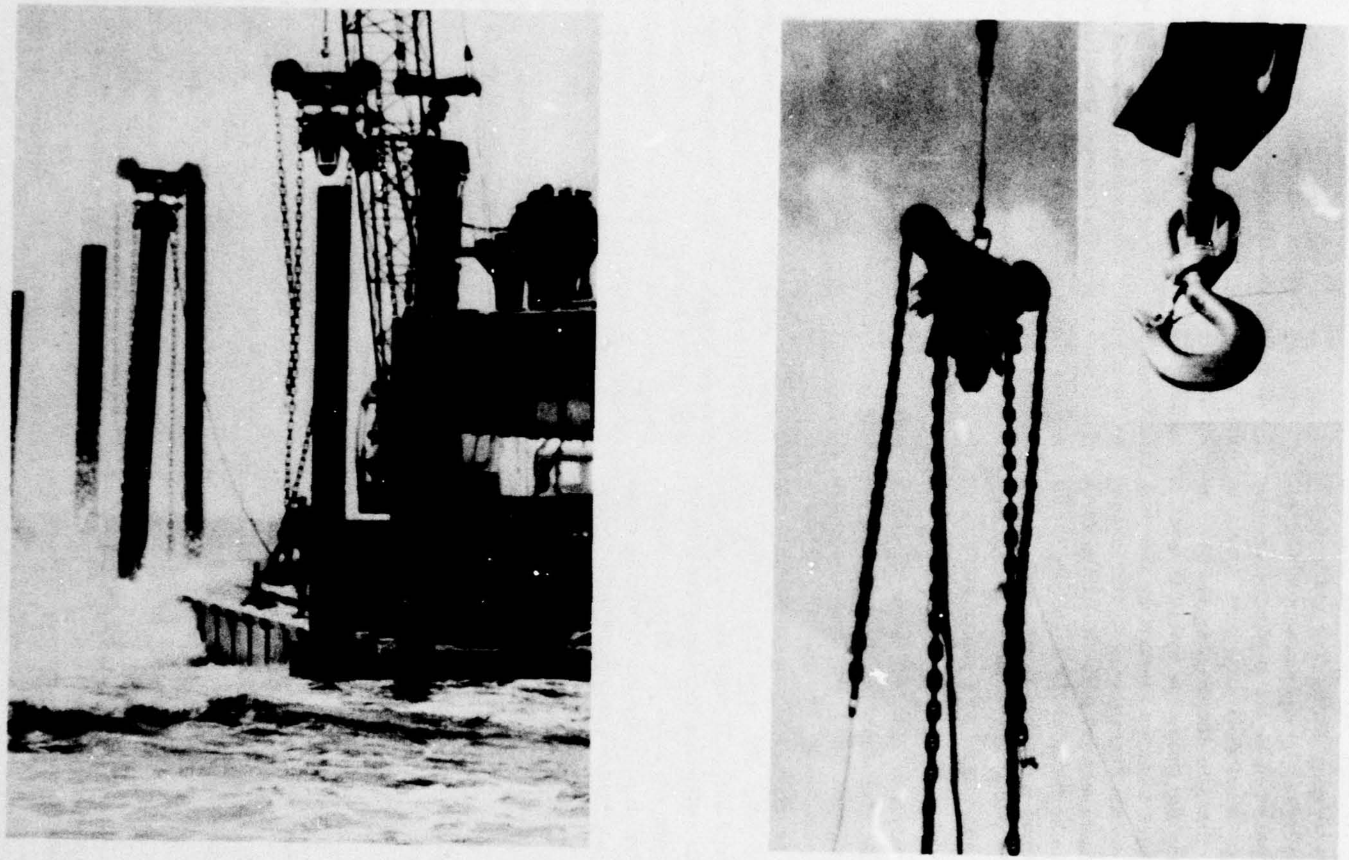


Figure B-9. Transporting jack/pile cap and mounting on pile with truck crane.

Engineering Analysis: The problems associated with the chains snagging on the deck and spudwells cannot be easily solved by equipment modification. The solution appears to be the elimination of these hazards through operational awareness. Operating personnel can eliminate the snagging problems by properly clearing the chains and hydraulic hoses as the jacks are lifted from the canisters by the truck crane located on the floating section. The snagging problems associated with the slack lift chain of a jack set on piling can be minimized by connecting the lift chain to the gimbal assemblies as soon as the jack is mounted on the piling. Even then, excessively slack chain can become snagged in a gimbal assembly or spudwell.

Recommendations: The lift crew supervisor should be made responsible for assuring that the chains and hydraulic lines are cleared prior to engaging the crane hook. The ends of the chains should also be loosely tied together to prevent losing the chain over the side should the latches be inadvertently withdrawn. Through training, all crew members should understand thoroughly the inherent danger of snagging chains on the elevated causeway and snagging gimbals or chains on the floating causeway once the jack has been mounted onto the pile of a floating section. At no time should a jack having slack chain in contact with the gimbal assembly, spudwell, or pontoon structure be left unattended.

Personnel: It is recommended that a lift crew supervisor be included to supervise this activity. Also, two more riggers are required to inspect for slack lift chain prior to lifting the floating section.

Type of Personnel	Observed		Recommended	
	No.	Rate	No.	Rate
Lift Crew Supervisor	–	–	1	EOC
Crane Operator	2	EO2	2	EO2
Riggers	8*	SN/SR	10**	SN/SR
Signalman	1	EO3	1	EO3

*Six on floating section, two on elevated.
**Eight on floating section, two on elevated.

Connecting Jacks to Causeway Section

Activity Analysis: Attaching the jack chain to the gimbal has two inherently dangerous aspects. The first is attaching a jack chain that is not long enough to allow for the pitching of the floating causeway section. This happened at one point during the Coronado test, causing the jack to be damaged as it was almost pulled off the pile. The second is trying to attach the chain to the outboard gimbal section. This requires that a man move out around the pile and fasten the chain; the causeway section could be pitching and experiencing wave action onto and around the spudwell.

Engineering Analysis: See Transporting Gimbal Plates and Gimbal Assembly of Lift System Mobilization.

Recommendations: A stand should be provided for riggers working on the outboard side of the external spudwells and/or a gimbal attachment method for the jack chain should be developed that does not require the rigger to work on the outboard side of the spudwell. It is recommended that the gimbal assembly hardware be improved, and the assembly methods be modified accordingly. Also, see Transporting Gimbal Plates and Gimbal Assembly of Lift System Mobilization.

Personnel: Two riggers were usually required to accomplish this task. When the jack lift chain was being attached to the outboard gimbal section, one man would support the jack idle chain for safety. Three SN/SR riggers are considered adequate for this task when supported by three SN/SR observers. It is recommended that a jack crew supervisor be added to supervise this activity. There exists sufficient time to make the attachment before another jack is ready for the same connection.

Activity: **CAUSEWAY SECTION ELEVATION**

Description: Once the jacks are installed and rigged to the gimbals, a section is ready to be elevated. This is performed by a diesel-powered control unit that is operated by one man. The four jacks can be operated simultaneously. The elevation activities were:

separation of the floating causeway sections prior to elevating, the elevation process itself, and causeway section reconnection. Descriptions, analyses, recommendations, and personnel requirements are provided separately for each of these activities.

Causeway Section Separation Prior to Elevating

Description: Prior to elevating a floating causeway section (sections elevated individually from beach seaward), it was necessary to disconnect the end connection to the next seaward floating causeway section. This is accomplished by lifting the end connector locking pins and raising that end of the section only. The lifting of the end connector locking pins was usually accomplished by waiting for wave action to release any forces on the pins and then lifting the pins free. In several instances, it was not possible to readily lift the locking pins in a normal manner due to binding of the end connectors. When this occurred, different methods of applying force to the pins were tried until they were released.

Activity Analysis: Once the end connector locking pins were released, the causeway sections separated themselves as the section to be elevated was lifted. Several problems were noted in accomplishing the locking pin release task. In one instance, a locking pin could not be released normally, and a crowbar was used in an unsuccessful attempt to release it. Finally, the locking pin had to be cut in two to permit separation. This problem was due to a horizontal curve in the causeway section (see Figure B-10) as discussed in the Engineering Analysis.

The number of personnel used to separate the causeway sections prior to elevating varied. A supervisor was always present, while the number of riggers varied. In view of the hazard potential of the operation, the number of riggers should be kept to a minimum.

Engineering Analysis: A 3-knot (1.54-m/s) long-shore current existed in the vicinity of the beached causeway. This current forced the causeway to sag in the horizontal plane between the pile pinned beach end and the pile pinned sea end (see Figure B-10). This sag kept the end-connecting links in tension on the port side of the causeway looking seaward and in compression on the starboard side. The separation difficulty caused by the long-shore current can be minimized by using dozers or a warping tug to straighten the causeway before dropping and driving the piles. A causeway beached in an area not having strong, long-shore currents would not exhibit such problems of section disconnection.

The normal elevating procedure during disconnection is to apply 100 tons (90.7 Mg) of uplift force on the end of the section to be disconnected (seaward end), leaving the other end (shoreward end) on slack chain. The male and female connectors separate by an amount proportional to the pitch of the section being elevated. This small amount of separation in conjunction with the round shape of the male end connector initiates wedging compressive forces against the sections being separated, thus forcing the two sections farther apart. As the separation increases, the wedging forces increase because of the curvature of the male end connector. Separation is completed when the floating section drops away from the end of the section being elevated. This method of separation worked satisfactorily in most cases.

The construction of a pier by not disconnecting sections is a possibility. The sections could be elevated in groups of two or more depending on the number and capacity of jacks.

The disconnection difficulties were minimized by properly positioning the truck crane on the floating section to act as deadweight in several instances.

Recommendations: A means of eliminating or reducing the possibility of end connector binding should be developed. It is recommended that when constructing a pier in those areas where a long-shore current exists, the horizontal curvature in the beached floating causeway should be corrected by using bulldozers, warping tugs, and broaching wires. Once the adverse curvature is removed, the causeway can be stabilized by setting several piles; then the bulldozers and warping tugs can be disconnected.

The possibility of elevating more than one section at a time end-connected using four or more jacks (multisection lifts) should be investigated.

Personnel: In the present method, one console operator, a supervisor, and a varying number of riggers perform the task. The number of riggers should be kept to a minimum for safety reasons.

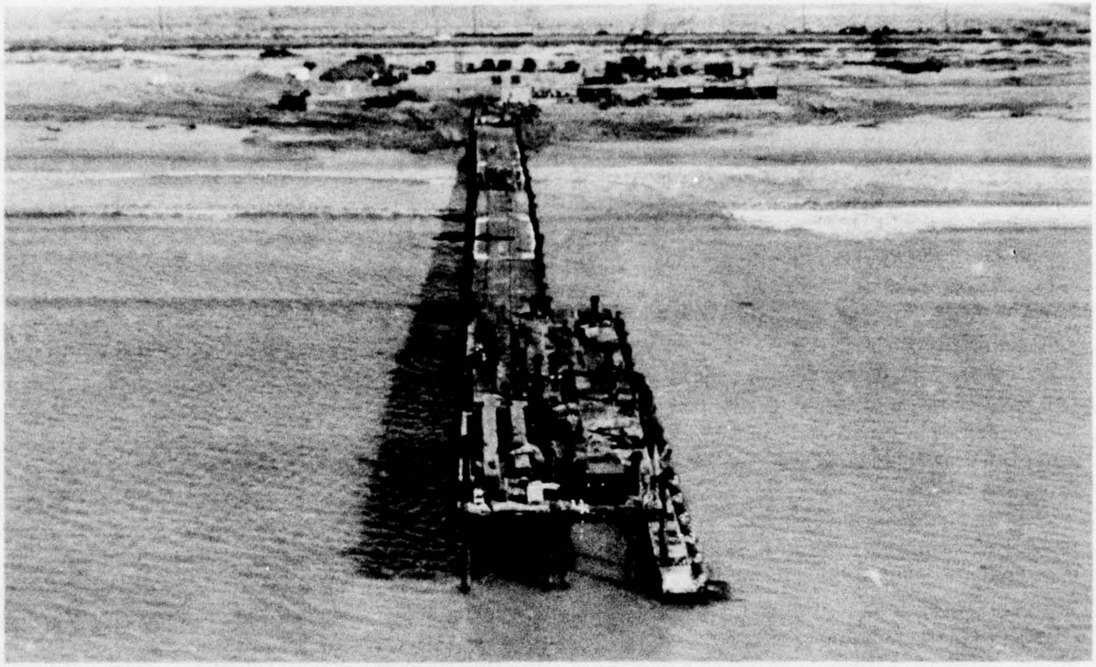


Figure B-10. Causeway separation difficulties caused by causeway curvature.

Type of Personnel	Observed		Recommended	
	No.	Rate	No.	Rate
Supervisor	1	EOC	1	EOC
Signalman	–	–	1	EO3
Console Operator	1	EO2	1	EO2
Riggers	3-8	SN/SR/EO2	3	SN/SR

Causeway Section Elevation (Figure B-11)

Description: Once the causeway section to be elevated has been separated from the next seaward floating section, the hydraulic power unit operator cycles the jacks individually or in some combination to elevate the section. The power unit was located at the seaward end of the previously raised causeway section, thus providing the console operator with a good view of all four jacks. In addition to the console operator, there were from five to six persons assisting him. Men were stationed near each of the four spudwells of the section to be lifted to observe and communicate the status of the lifting gear to the console operator directly or via a signal relayer stationed at the seaward end of the elevated causeway section. Lift latch operation is signaled by the observer (see Figure B-11) by placing his hands over his head and orienting his thumbs inward when the latch is engaged or outward to indicate the unlatched condition. Hold latch status is signaled with the arms at the sides and thumbs oriented as described above. The observers also communicated causeway lifting progress and status information. Causeway section elevation proceeds until the end connectors of the elevated sections overlap, at which time it is necessary to separate and align the connectors so that they can be connected to allow final elevation to be accomplished. Details of the elevation procedure in terms of console operation are presented separately.

Activity Analysis: The method of elevating the causeway sections is straightforward, and no apparent problems were evident. The primary time limitation in causeway elevation is the lift rate, which is

approximately 25 ft/hr (0.2 cm/s), including lift and hold operations. Nominal elevation times range from 20 to 30 minutes, depending upon the height to be raised and the amount of individual jack cycling that is required. There is a definite but remote possibility that equipment damage and/or personnel injury could occur if the jack control unit operator inadvertently retracted the hold and lift latches simultaneously when there was no load on the jack while connected to a floating causeway section.

Engineering Analysis: Causeway elevation with the present control system requires caution in two areas: (1) observers are required at each jack to make certain everything is in working order, and (2) the control console operator has to perform several operations during the elevating sequence.

The four jack observers have to be familiar with the following:

1. Hydraulic hose entanglements with hardware
2. Lift chain twists
3. Jack idle wheel performance
4. Jack latch performance
5. Hydraulic leaks
6. Jack idle chain entanglements with hardware
7. Gimbal performance
8. Gimbal connections
9. Overall jack performance
10. Compensator performance
11. Spudwell performance

The console instrumentation with its dial gages and latch position indicator lights gives the operator visual feedback. The operator should be aware of operational ranges and limitations. The latch positions are also verified by using hand signals (Figure B-11). When an abnormal reading occurs during the operation, the trouble can be rectified through predetermined diagnostic procedures. Should jack malfunctions occur during the elevating process, individual jacks can be removed for repair or replacement. It is believed that problem areas can be and have been minimized, but cannot be eliminated, through hardware design. Detailed descriptions of control console operations, diagnostic procedures, and jack removal are described in Reference 5.

Console operations can be simplified by automation of certain control functions. This eliminates some control the operator has over his equipment, however. Through experimentation with automatic control devices, an optimum semi-automatic system can be designed that possesses the characteristics of manual and automatic controls best-suited to this operation.

A 1/2-inch (1.3-cm) nylon line should be attached from the free end of the idle chain to the gimbal assembly handles at all times during jack operation. As the causeway section is lifted, the slack should be removed from this line. This line prevents inadvertent chain movement through the jack should both latches be simultaneously extracted. The 1/2-inch (1.3-cm) line should be handled only when elevating is halted and the lift and hold latches are closed; this prevents chain movement that could be very dangerous to personnel.

Recommendations: It is recommended that each of the four jack observers have manual override control of the hydraulic power for his jack. It is recommended that the free end of the slack idle chain be attached to the gimbal assembly with 1/2-inch (1.3-cm) nylon rope at all times during jack operation. This line should not have more than 3 feet (0.9 m) of slack at any time, and the slack should never be taken out during jack operation. It is further recommended that automated or semi-automated control of the lift system be explored.

Personnel: The present method, which requires five to six observers/signalmen to provide the console operator with equipment status information, is recommended.

Type of Personnel	Rate	No.
Console Operator	EO2	1
Signalman	EO3	1
Observers	SN/SR	4

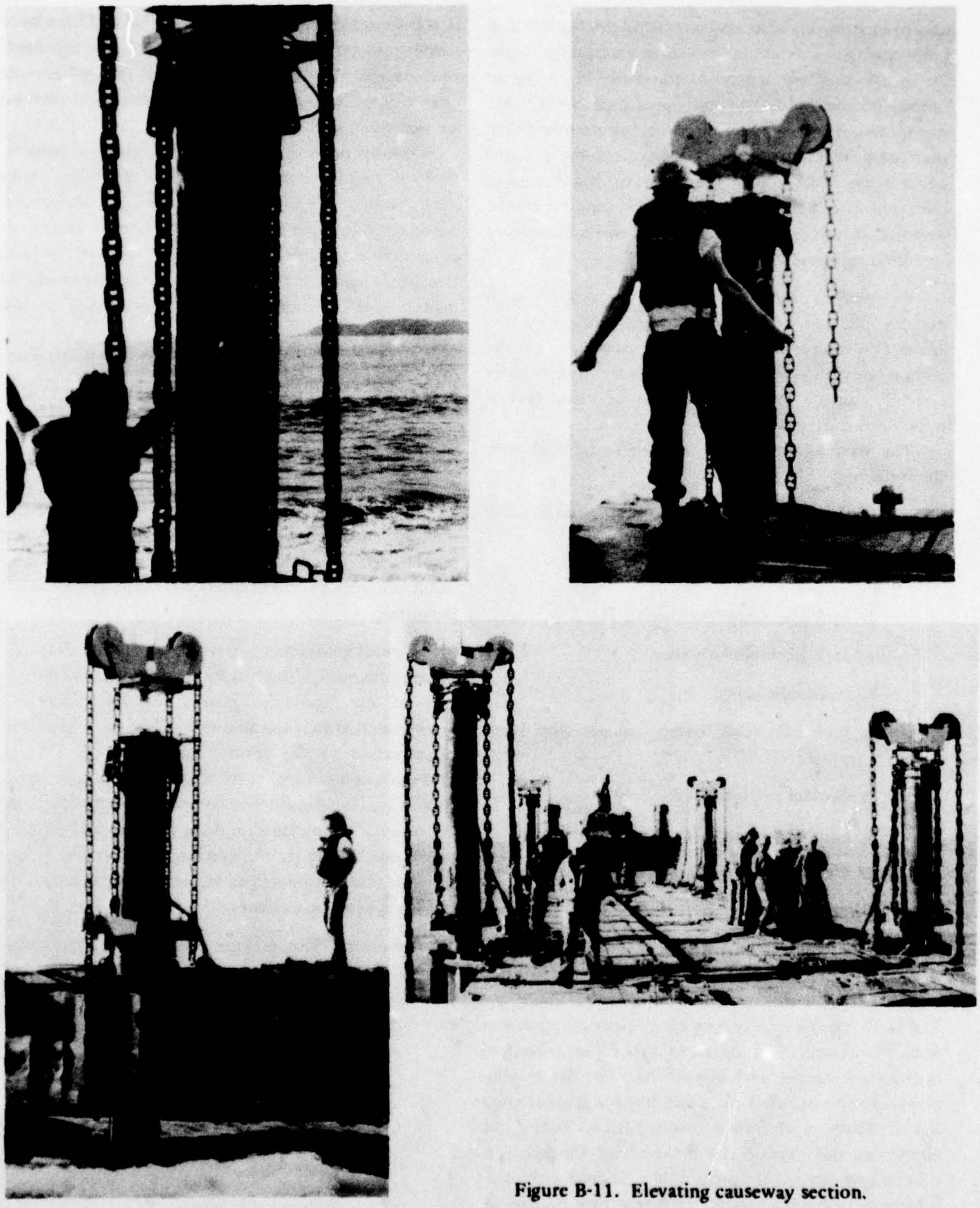


Figure B-11. Elevating causeway section.

Causeway End Connection After Elevation (Figure B-12)

Description: As the causeway section continues to be raised, it reaches a point where its end connector is overlapped by the previous fully elevated causeway section. In order to continue with the causeway section elevation, i.e., make the height of the ends of the two sections the same, it was necessary to employ a scissoring or wedging action between the sections by lifting with appropriate jacks.

After a causeway section has been elevated to the height of the previously raised section, it must then be connected by means of the end connector locking pins. The ends of the two causeway sections are invariably laterally misaligned and separated by several inches. It is first necessary to align the end connectors, then the sections are pulled together to complete the connection. This task took approximately 15 minutes toward the end of the causeway elevation operation.

Activity Analysis: One problem noted during the connection of the elevated causeway sections was the occasional snagging of the alignment cable on various deck protrusions or components as the cable was initially pulled in by the bulldozer winch. Damage to the wooden decking also occurred whenever the bulldozer was used. A potential hazard exists in the handling of the 1-1/8-inch (2.9-cm) steel line, rigging of the snatch block, and the winching operation when the cable is under high tension. Methods for safe and easy rigging of snatch blocks or other types of rigging components should be explored.

Engineering Analysis: During the final stages of section elevation, the end connector of the elevated section has to be connected to the end connector of the previously elevated section. Because of the ball and socket configuration of the end connector, the sections had to be separated and then drawn together to complete the connection. Alternate elevating techniques are possible that do not require disconnection/connection (see Engineering Analysis of Causeway Section Separation). The techniques that proved most effective in connecting the elevated sections were a combination of pile-positioning/jack operation sequencing and winching. To maximize section separation after elevating, the piles were tilted toward the sea end of each section during driving. The sections were then not elevated vertically, but were allowed to follow the tilted pile during lifting, moving seaward several inches. In most cases this method of gaining end connector clearance proved effective.

The connection of the sections progressed with the pitching of the end to be connected upward, thus giving additional clearances and the application of 100 tons (90.7 Mg) of lift force on that end only. (See Engineering Analysis of Causeway Section Separation for explanation of connection separation by pitching of section and wedging effects.) Once the female and male connectors were positioned at the same elevation, the connections had to be aligned laterally and the sections drawn together. This was accomplished effectively using the winch of a TD-25 tractor and a wire rope sheave. A 100,000-pound (45.4-Mg) force could be applied to both sections simultaneously with the tractor on the section previously elevated and one wire rope sheave mounted on the section just elevated. (See Figure B-13 for force required for pulling an elevated section.) The direction of the force could be easily controlled by sheave dead end and tractor location, thus accomplishing lateral and longitudinal alignment simultaneously. After correct alignment was attained, the connecting pins were dropped, completing the connection.

The horizontal curvature in the causeway caused by the long-shore current caused the same problems connecting as were inherent in disconnecting. The problems could be minimized by using tugs and tractors as suggested in the Engineering Analysis of Causeway Section Separation activity.

The use of hydraulic or mechanical equipment to exert the forces required to make the connection instead of using a dozer winch is possible. The practicality of a piece of additional equipment replacing a piece of existing equipment (dozers are required for beaching, etc.) that has been proven very effective for a given task is doubtful. Even if the additional equipment proved effective, it would be redundant, as tractors would be available to perform these duties.

Recommendations: If the current method of connecting elevated causeway sections, which utilizes the bulldozer, is to be used in the future, some means of protecting the wooden deck or a different type of

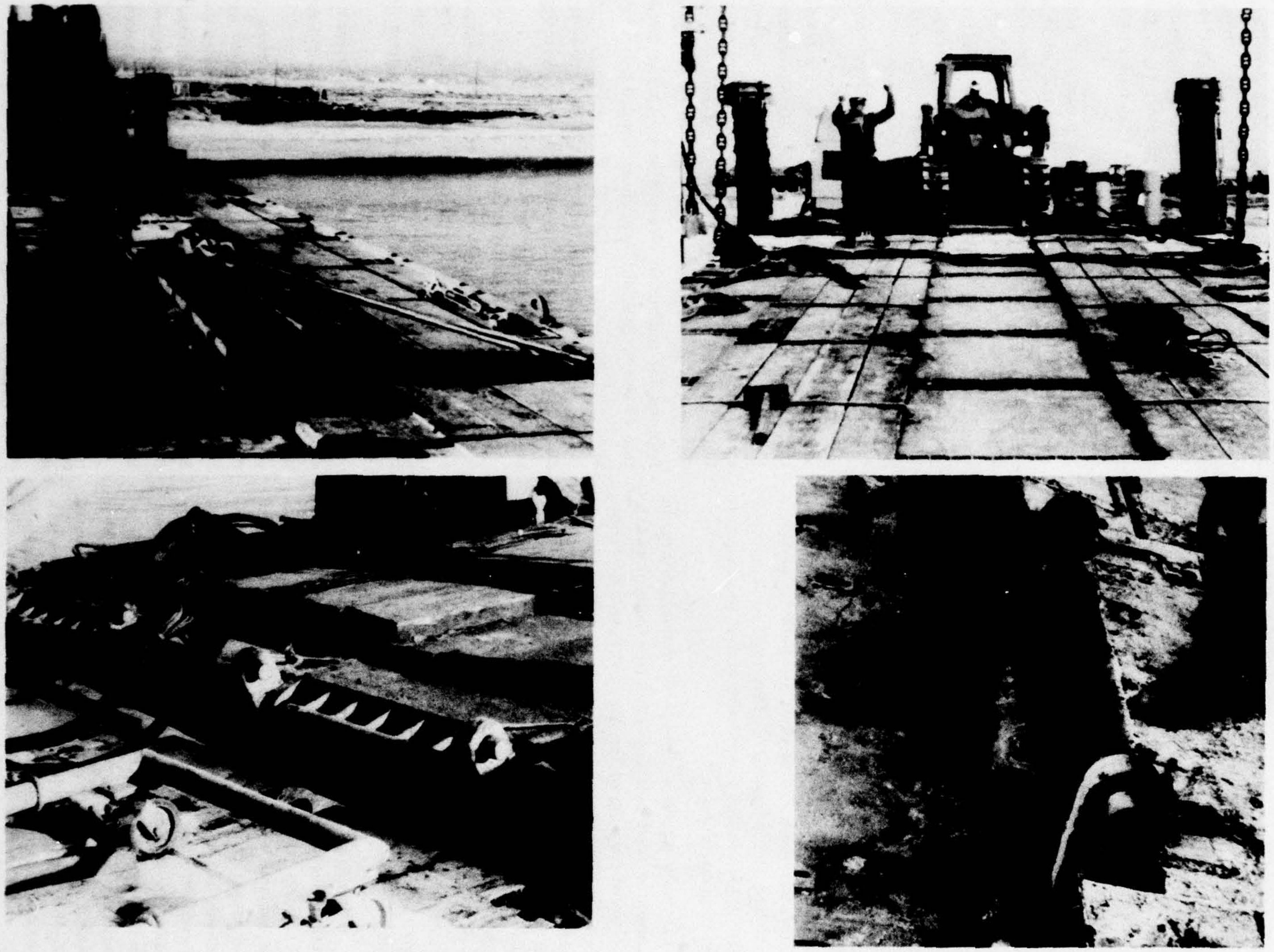
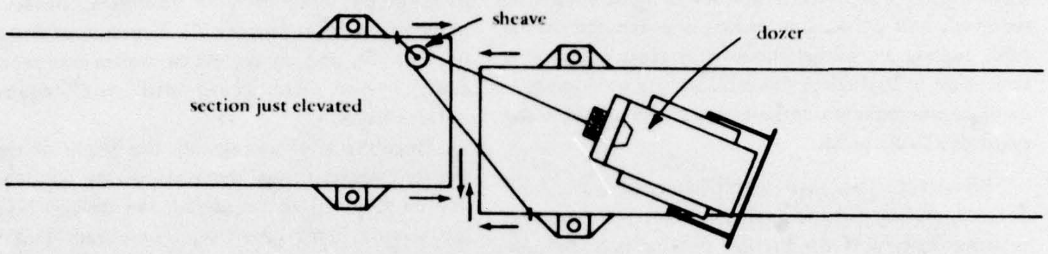


Figure B-12. End-connecting causeway after elevation.



Pulling sections together using sheave and dozer winch.

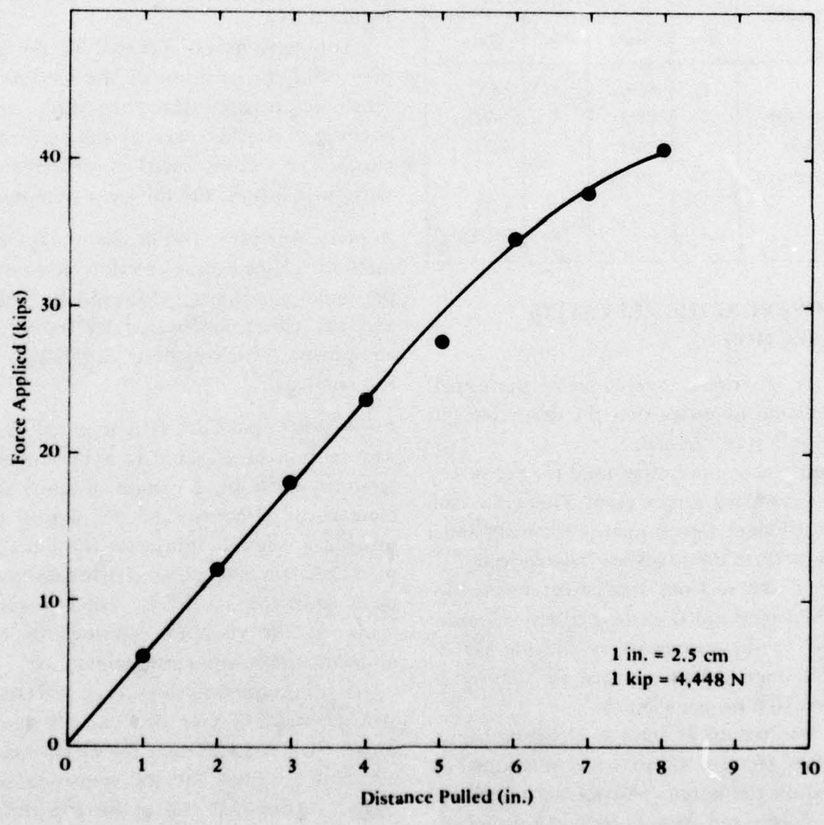


Figure B-13. Approximate pull required to move a causeway section while elevated.

decking material should be provided. In the former case, street pads on the bulldozer tracks should be used. Extraneous components on the deck should be removed, and permanent protrusions avoided during cable rigging. Personnel should stay clear of the area as tension is applied to the cable during section alignment to minimize potential injury to personnel in the event of a cable break.

Personnel: The task was performed by a bulldozer operator, console operator, supervisor, and two to three riggers. If the present method is to be continued, it is recommended that four riggers and a signalman be used.

Type of Personnel	Observed		Recommended	
	No.	Rate	No.	Rate
Supervisor	1	EOC	1	EOC
Bulldozer Operator	1	EO2	1	EO2
Console Operator	1	BM2	1	EO2
Observers/Signalmen	2-3	SN/SR	–	–
Signalman	–	–	1	EO3
Riggers	–	–	4	SN/SR

Activity: **SURVEYING THE ELEVATED CAUSEWAY SECTION**

Description: A continual survey was performed during the elevation to insure that the desired height of the section deck was attained.

The personnel and equipment used for the survey were that of a standard survey crew. This crew consisted of an instrument (level) man, a rod man, and a notekeeper to perform the necessary calculations.

The slope of the sections was predetermined by dividing the final pierhead deck height desired above the beach end of the causeway by the number of sections to be sloped. This resulted in an average slope of 2.5 feet (0.8 m) per section.

The level was set up as soon as elevating began. For the first four sections the level was positioned on a truck parked on the beach. This location provided the necessary height and view as well as keeping the level free of movement from vibrations (see Figure B-14). Operation in this mode was greatly aided by equipping the rod man and the instrument man with walkie-talkies. After the fourth section the distance between the instrument and the rod became too great to accurately read the rod. Therefore, the level was moved to section four for the elevation of five and to five for six, and so on. When within one section of each other, the team did not require the walkie-talkies.

Once the level was set up, the height of the next elevated section was determined. By knowing the desired slope of the roadway, the desired height of the section being raised was computed. This height was then marked on the sea-end corner piles during the final stages of section elevation. The beach end of the section being elevated was brought to the same height as the sea end of the previously elevated section by visual comparison with a straightedge (see Figure B-14).

The section was elevated to the marks on the piles, and the position of the section was checked. Small adjustments were then made, and, if deemed necessary, another survey was performed as a final check. The section was then secured to the pile caps with turnbuckles, and the jacks were released.

Activity Analysis: The problems associated with this method of causeway section alignment were (1) personnel movement, which blocked the line of sight; and (2) vibrations caused by movement of heavy equipment, which made it difficult to take accurate rod readings.

Engineering Analysis: It is required that each causeway section be elevated to a prescribed height. The pierhead must be a certain distance above the surf zone to be effective, and the sloping sections must provide a smooth transition from the beach to the pierhead. It is also required that causeway strength be maximized for live loads, which requires the dead loads on the causeway sections to be equal and uniform at the suspension points.

It is necessary to slope each transition section to gain a sufficient pier deck height above mean low water. This requires that the clearances between the pile and spudwell for the transition sections be at least 3 inches (7.6 cm) at the top and bottom such that the section can be pitched upward without the pile binding and exceeding the 100-ton (90.7-Mg) capacity for the two jacks on the high end of the section. The clearances between spudwell and pile for

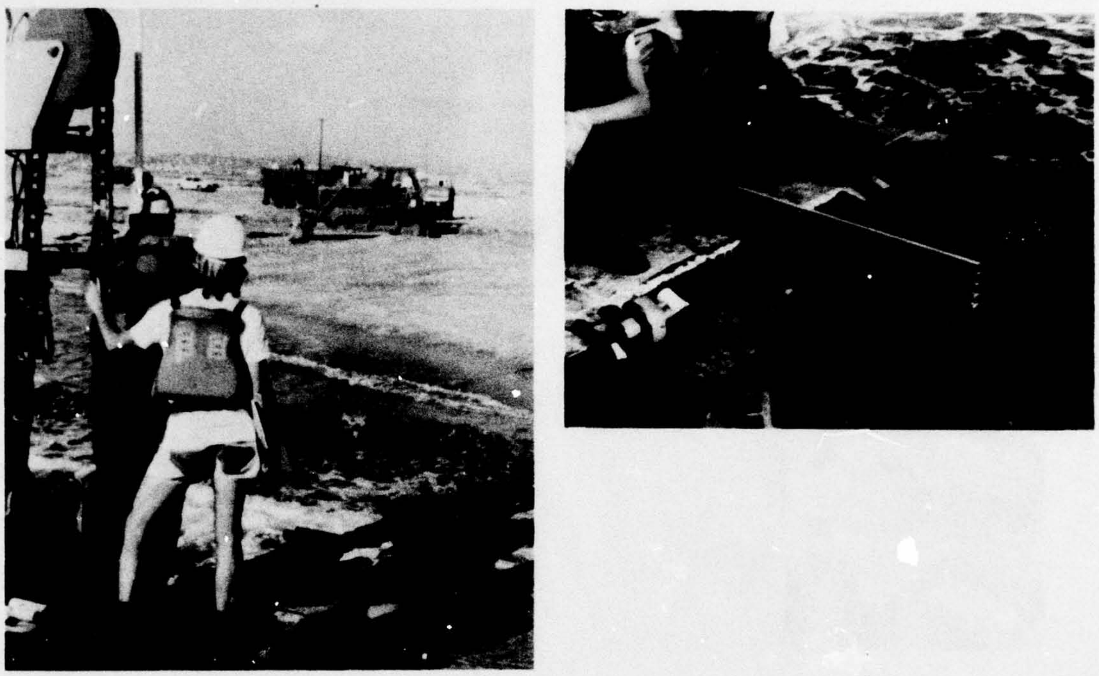


Figure B-14. Surveying the elevated causeway sections.

those sections not pitched, but elevated into a horizontal position, could be reduced to 1/2 inch (1.3 cm).

To obtain a smooth transition and pierhead height, the pier can be constructed within a vertical tolerance of ±1/4 foot (6.6 cm) for each section in the longitudinal direction, assuming the sections are all end-connected after elevation. However, to insure uniformity of loads at the suspension points, the adjacent lateral supports of each section must be within 1 inch (2.5 cm) of each other in height. This will insure that the torsional loading of each section is minimized. The requirements of both a smooth transition and minimal torsional loading can be obtained by surveying only the sea end of each section.

Recommendations: It is recommended that personnel and equipment movements be halted while the survey is being taken.

Personnel:

Type of Personnel	Observed and Recommended	
	No.	Rate
Console Operator	1	EO2
Surveyors	3	EA
Signalman	1	EO3
Riggers/Observers	4	SN/SR

Activity: **SECURING CAUSEWAY SECTION TO PILE** (Figure B-15)*

Description: After the final adjustments in causeway section elevation have been completed and surveyed as being correct, the pile caps are secured to the

*This section and the subsequent one on welding piles to the causeway section will be revised when the mechanical pile-to-causeway connection development and evaluation are successfully completed. See Volume III for a discussion of the mechanical connection.



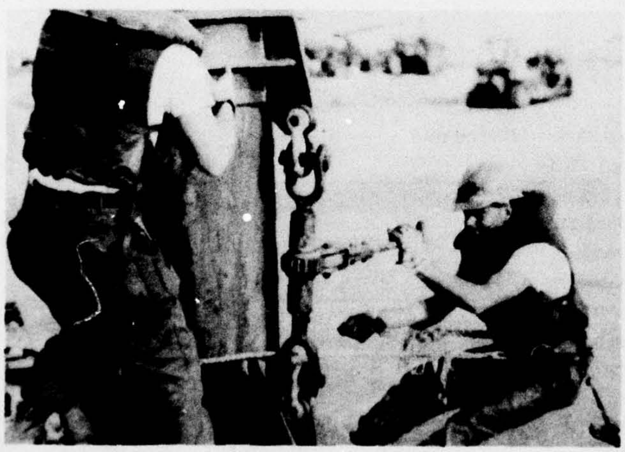



Figure B-15. Securing elevated causeway section to pile.

causeway section by means of two turnbuckles attached to opposite sides of the cap and spudwell. The jacks are then cycled, and the load is transferred from the jack and gimbals to the turnbuckles and associated chain linkages. This permits the jack and gimbal assembly to be removed from the pile of the elevated section and transported to the floating section pile. Two and sometimes three riggers secured the pile cap padeyes to the padeyes on the causeway section spudwell. The console operator is also required to operate the console during the transfer of the section load from the jack/gimbal to the pile cap temporary connection system. The individual subtasks comprising this activity are:

- Transport turnbuckles, chain links, and shackles to each corner of elevated section
- Assemble above to approximate required length
- Rotate turnbuckles to take up slack, then tighten
- Transfer load from jack chains to turnbuckle assemblies using control console

The turnbuckles, chain links, etc., were hand-carried to the corners of the elevated section. The turnbuckle assembly was usually attached to the pile cap and spudwell padeyes with shackles, although detachable chain links were also used. Two men usually worked together assembling, attaching, and securing one turnbuckle assembly before proceeding to the next assembly. A different type of turnbuckle that incorporates a ratchet was sometimes used instead of the conventional-type turnbuckle. It took approximately 15 minutes to secure the turnbuckle assembly to one pile cap and spudwell padeyes, including preparation, assembly, and turnbuckle tightening.

Activity Analysis: This activity is considered to be straightforward, and no major problems were noted. There is a potential safety hazard when performing the task on the outboard section of the external spudwells without the use of a safety harness.

The slack in the chain can be taken up more quickly with the conventional turnbuckle than with the ratchet-type turnbuckle. However, the final tightening of the assembly from pile cap to spudwell padeye is somewhat faster and more positive with the ratchet-type turnbuckle, because there is no need to slide a lever rod through the turnbuckle eye after each half turn.

The pile cap/causeway section connection scheme is a temporary, but quick method of securing the causeway section to the piles so that the jacks can be transferred to the next causeway section prior to completion of the time-consuming welding operation. An alternate method of attaching the causeway sections to the piles could conceivably eliminate this temporary method of connection.

Engineering Analysis: The pile cap as a piece of causeway temporary suspension hardware or jack adapter could be eliminated when used with 20-inch (50.8-cm) OD pipe pile and a pinned-suspension system.

The suspension system that could replace pile caps, turnbuckles, shackles, and chain is a pile-pinning arrangement. Four 4-inch (10.2-cm) square steel pins, each approximately 3 feet (0.9 m) long, would be inserted through the pipe pile (one for each pile) beneath the elevated causeway section. A pinning hole would be burned through the pile above the deck of the section during the final stages of the elevating process. The section would then be elevated past the pinning holes, and the pins inserted beneath the section from within the internal spudwells. The pins could be inserted beneath the external spudwells from personnel walkways attached to the spudwell.

Portable personnel walkways that can be attached to the external spudwells can be developed. These would appreciably reduce the hazards for personnel working around the pile while standing on the spudwell. The arrangement for connecting the gimbal assemblies to the lift padeyes can be improved.

Recommendations: A safety harness should be used whenever personnel work on the outboard side of the spudwell. The conventional turnbuckle is preferred over the ratchet-type turnbuckle because the slack in the connection between the pile cap and spudwell can be taken up more quickly. It is recommended that a hooked rod be used during final tightening of the turnbuckle to minimize the possibility of the rod slipping out of the eye of the turnbuckle. Shackles should be used to attach the turnbuckle assembly to the pile cap and spudwell padeyes, because they are easier to attach than the detachable links.

Turnbuckles, detachable links, or shackles should be pre-positioned on the causeway section to reduce delays in performing the task due to transport of these items.

It is recommended that a causeway/pile attachment method, such as the pinned-connection, be developed that would eliminate the need for the temporary pile cap/causeway section connection and possibly the welding operations. Portable personnel walkways are recommended to be used during all external spudwell activities.

Personnel: The following riggers (SN/SR) are considered adequate to accomplish the task as currently performed when the pile cap is:

Less than 5 feet (1.5 m)	4
Between 5 and 7 feet (1.5 and 2.1 m). . .	6
More than 7 feet (2.1 m)	8

above the deck of the causeway. A task supervisor (EOC) is required.

Activity: **WELDING PILES TO CAUSEWAY SECTIONS** (Figure B-16)

Description: When the turnbuckles are connected to the pile caps and spudwells and the load is transferred from the jacks to the pile cap/turnbuckle assembly, the piles are arc-welded to the spudwell. Steelworkers first weld four gusset plates at the causeway deck level; one steelworker is assigned to each pile. Sometimes three or four steelworkers would work simultaneously on separate piles. The four gusset plates took approximately 1 hour to weld. Once these four gusset plates were welded to a pile, four additional gussets were then welded to lower members of the spudwell. This also took approximately 1 hour. CB welders were supplemented by three or four PWC welders.

Activity Analysis: The time to elevate a causeway section using current methods was estimated to be 4 hours and 20 minutes. If 8 man-hours are required to weld four piles to a causeway section, a minimum of two welders is necessary. If the causeway elevation rate is increased, a directly proportional increase in the number of welders would be necessary if the present method of connecting the piles to the causeways is to be continued. A 1.06-hour/causeway erection time using eight jacks to elevate three causeway sections simultaneously is predicted. Therefore, it would require 24 man-hours/3.18 hours, or eight welders as a minimum working simultaneously.

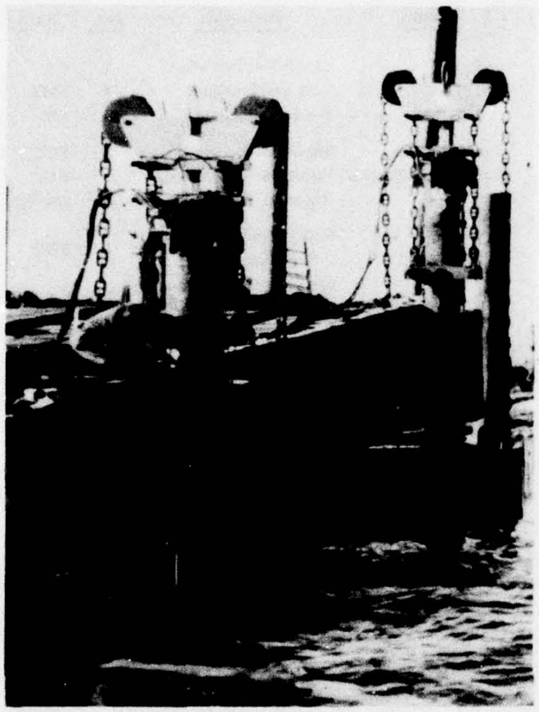
Some of the problems noted during the welding operations were:

- Interference between welders/equipment and other operations.
- Stand used by the welder when welding from an over-the-side location was too narrow.
- Welding generators too noisy.
- Likelihood of personnel tripping over welding equipment cables.
- Welding equipment being left exposed overnight, causing poor operation on the following morning.

Engineering Analysis: The welded gussets could be replaced by a pinning arrangement. Four 4-inch (10.2-cm) by 3-foot (0.9-m) long steel pins (one for each pile) would be inserted through the pipe pile beneath the elevated causeway section. A pinning hole would be burned through the pile above the deck of the section during the final stages of the elevating process. The section would then be elevated past the pinning holes, and pins would be inserted beneath the section from within the internal spudwells. Longer pins could be inserted beneath external spudwells from personnel walkways attached to the spudwell. Wedges could then be inserted between the spudwell and the pile, providing a rigid spudwell-to-pile connection.

Recommendations: It is recommended that an alternative method of permanently connecting the piles to the causeway section, such as the pinned connection cited, be developed to reduce manpower and equipment requirements, which would increase as the causeway elevation rate is increased.

If the present method is to be retained, it is recommended that welding operations lag elevation of the causeway sections by two causeway sections in order to minimize work interference, safety hazards, and potential equipment damage. After the last causeway sections are elevated, it is recommended that the maximum number of available welders be applied to welding so that crane transport and container



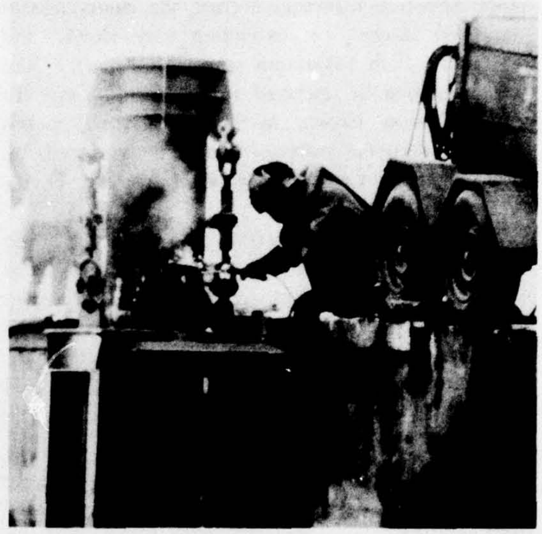


Figure B-16. Welding piles to a causeway section.

off-loading and transfer operations will not be held up. Quieter generators should be used or the present one acoustically modified to reduce the noise level. The stands for over-the-side welding should be approximately 2 feet (0.6 m) wide and contain a safety rail. Supervisors should instruct welders (as well as other personnel) to put away and/or cover equipment after each day's operations to prevent damage from salt sea air. It is also recommended that the temporary suspension (see Securing Causeway Section to Pile Cap activity) and the permanent connection be incorporated as one connection.

Personnel: The number of welders used to weld the piles following causeway elevation varied. The minimum number of welders depends upon the causeway elevating rate and the time required to weld the four piles – approximately 8 hours for one welder. A minimum of two welders is considered necessary based upon the observed causeway elevation time of 4.33 hours per causeway section with one section being elevated at a time.

Type of Personnel	Observed		Recommended*	
	No.	Rate	No.	Rate
Welder/Supervisor	1	SW3	–	–
Welders	6 min	SWCN	3	SWCN
Riggers	–	–	6	SN/SR

*Pinned connection method

PIER RETRIEVAL

The first step of pier retrieval was to remove the fendering system by pulling its fender piles and towing it away. This was followed by disconnecting Pierhead Sections No. 3 and 4 and lowering them to the water end-connected. The piles of Sections No. 3 and 4 were pulled, and then these sections were towed away. Simultaneous lowering of two sections was done by placing two jacks per section across a diagonal of the section. The two jacks could lift

[approximately 1 inch (2.5 cm)] the chain clear of the hold latches by extending very slowly and developing their maximum static lift capacity. The jacks can then be operated at their normal rate for the retraction stroke. Methods for simultaneous lowering of two or more sections (end-connected) are discussed in the Causeway Section Lowering Activity of Pier Retrieval.

The five approach sections were then separated from the pierhead, and lowering of the five sections was begun. These sections were left end-connected to evaluate the method of multisection lowering. This left Sections No. 1 and 2 of the pierhead as the only remaining elevated sections. The hydraulic crane had been left on these sections to place the jacks for the lowering of these sections.

After all sections were lowered, they were reconnected. The truck crane was used to remove the jacks from Sections No. 1 and 2. The piles remaining in the causeway were then pulled. The ramps to the beach were removed, and the causeway was retracted from the beach.

The procedures of many activities performed during pier construction are reversed during pier retrieval. For instance, in pier construction the jacks are removed from the piles by a hydraulic crane positioned on the elevated sections, and in pier retrieval a hydraulic crane replaces the jacks on the piles while the section is still elevated. While the location and personnel have not changed, the procedures of the activity have been reversed.

These reversals will be noted and the reader referred to the corresponding "Pier Construction" activity where necessary. Some activities are unique to pier retrieval and, therefore, are described and analyzed as new activities herein.

During pier retrieval the personnel teams remain the same as during pier construction. The construction team (floating section) reconnects sections after they are lowered, disconnects jacks, and disassembles and transports gimbals to the next elevated section. The gimbals are then assembled at the next jack location by the construction team (elevated section), who also separate sections where necessary.

The jacking team lowers the sections and moves the console and jacks. The teams are as follows:

Team	Personnel	No.	Rate
General	Beach Commander	1	LT
	Communications	3	SM3
	Welders/Burners	4	SW
Construction (elevated section)	Supervisor	1	EOC
	Equipment Operator	1	EO2
	Riggers	8	SN/SR
Jacking	Equipment Operator/ Supervisor	1	EO2
	Equipment Operator/ Signalman	1	EO3
	Riggers/Observers	4	SN/SR
Construction (floating sections)	Supervisor	1	EOC
	Equipment Operators	2	EO2
	Equipment Operator/ Signalman	1	EO3
	Riggers/Observers	6	SN/SR

Activity: **REMOVING WELDED CONNECTION OF CAUSEWAY SECTION TO PILES**

Description: Before an elevated causeway section could be lowered, the gusset plates had to be removed to free the section from the piles.* This was done by cutting the gusset plates with an oxyacetylene torch. The welders had no trouble staying ahead of the jacking crew once section lowering commenced. With a team of two welders, gusset plate cutting took about 1 hour per section.

Activity Analysis: Problems encountered in the removal of the gusset plates were:

(1) A delay in the section lowering process while waiting for the first section to be freed.

(2) Stand used by welders on the external spudwells was too narrow.

Removal of the gusset plates is a straightforward process that presents no major cutting problems. To avoid an initial delay, the cutting of the gusset plates should commence with or before the start of the installation of the jacking system.

Engineering Analysis: To eliminate the problems personnel have when working over the side on the external spudwells, portable ramps should be developed. These ramps should provide a more stable platform for both welding and cutting operations.

*This activity is unique to Pier Retrieval.

The development of a connection system that would eliminate the welded connection is discussed under Welding Piles to a Causeway Section Activity in the Pier Construction Section. This connection involves a pinning method that eliminates welding.

Recommendations: It is recommended that the cutting of the gusset plates commences before or as soon as the jacking system installation is begun on the first section to be lowered. After this, the cutting should maintain a one-to-two section lead on the lowering of sections.

Larger work platforms are recommended for personnel welding or cutting on the external spud-wells.

It is recommended that an alternate connection (pinned connection) replace the welded gusset connection system.

Personnel: The number of welders (SWCN's) used to cut the gusset plates varied, with the most being used to ready Sections No. 3 and 4 for simultaneous lowering. After this, the crew was reduced from four to two or three without creating any difficulties in staying ahead of the lowering. A welder/supervisor (SWCN) is required to oversee the gusset plate cutting.

Activity: **LIFT SYSTEM MOBILIZATION**

Description: The lift system mobilization operation was subdivided into nine activities as follows:

(1) Transporting jack control console

(2) Disconnecting jacks from causeway section

(3) Gimbal disassembly

(4) Transporting gimbal plates

(5) Gimbal assembly

(6) Removing jack from pile

(7) Rigging of jack and mounting on pile

(8) Connecting jacks to causeway section

(9) Removing pile caps and associated hardware

These activities are concerned with the movement and installation of the jacking system and associated hardware. Location and operation of the jack and separation and connection of the causeway sections are discussed in Causeway Section Lowering Activities. Because the lowering methods varied, the movement of the jacks varied. When going from a lowered causeway section to one that is still elevated, the truck crane removes the jacks from the piles, and the hydraulic crane places the jacks on the piles of the section to be lowered next. The gimbal plates must be lifted by one of the cranes, and two separate crews are required to carry them.

After lowering is completed, the lift system is ready to be mobilized. This refers to all four jacks when lowering the sections one or two at a time and to two jacks when lowering the sections end-connected.

Disconnecting the jacks from the causeway section and disassembling the gimbals are continuous activities done by members of the construction team (floating). These occur simultaneously with the movement of the jack control console to the next section by the jacking team. Members of the construction team (elevated) begin transporting the gimbal plates to the next pile location, where the gimbals are assembled by the construction team (elevated).

Once the control console has been moved and the construction team (floating) is clear of a jack, that jack is removed, rerigged, and mounted on the next pile by the jacking team. The jack is then attached to the previously installed gimbals. Once the jacks are attached to the causeway, the causeway section is lifted slightly to facilitate in the removal of the turnbuckles from all the piles of the section. The pile caps are then removed from the piles without jacks using the hydraulic crane and taken with the turnbuckles and chain to the beach.

Detailed descriptions of the individual activities for pier construction are given in "Pier Construction." Note that these activities are done in reverse for Pier Retrieval. Reverse operations are noted for the following Retrieval Activities.

Activity: **Transport of Jack Control Console**

See "Transporting Jack Control Console" of Pier Construction for the basic methods and analysis of transporting the jack control console. In pier retrieval there are fewer problems in moving the console when the sections remain end-connected. The adaption of the console to be self-propelled would greatly aid in its movement.

Activity: **Disconnecting Jacks From Causeway Section**

See "Connecting Jacks to Causeway Section" of Pier Construction. The procedure is reversed for pier retrieval. A personnel ramp mounted on the external spudwells is highly desirable. Personnel and equipment for this activity remain the same as for the "Connecting Jacks to Causeway Section Activity" of Pier Construction.

Activity: **Gimbal Disassembly**

This procedure is the reverse of the "Gimbal Assembly" procedure of Pier Construction. The analysis and recommendations for the gimbal assembly activity of Pier Construction are applicable for gimbal disassembly.

Activity: **Transporting Gimbal Plates**

See "Transporting Gimbal Plates" of Pier Construction. The gimbal plates are transferred from lowered sections to an elevated section. The number of personnel required remain the same as cited for this activity, except when the sections are lowered end-connected. This method of lowering eliminates the need to handle gimbal plates with a crane and allows the plates to be hand-carried directly from pile to pile. This allows four men to complete this task instead of the eight required in Pier Construction.

Activity: **Gimbal Assembly**

This procedure is the reverse of "Gimbal Disassembly" of Pier Construction. The equipment and personnel remain the same.

Activity: **Removing Jacks from Pile**

This procedure is the reverse of the procedure of "Transporting Jack/Pile Cap and Mounting on Pile" of Pier Construction. The jack is picked from the pile with the pile caps and placed in a jack recycling canister. The equipment and personnel remain the same.

Activity: **Rigging of Jack and Mounting on Pile**

This activity is the reverse of the "Transporting and Rigging of Jack" of Pier Construction. The chains are recycled to the lowering position, the pile cap is removed, and the jack is transported to and inserted in the pile cap of the next pile. The pile cap was installed on the pile during pier construction. The equipment and personnel remain the same.

Activity: **Connecting Jacks to Causeway Section**

This if the reverse of the "Disconnecting Jacks from Causeway Section" cited for Pier Construction. The analysis, recommendations, and personnel do not change.

Activity: **REMOVING PILE CAPS AND ASSOCIATED HARDWARE***

Description: Once the jacks are in place on the piling and attached to the section, the section is raised to free the turnbuckles connecting the section to the pile caps. The turnbuckles are then manually removed. The pile caps are removed from piles without jacks using either the hydraulic crane or the rough terrain forklift. This rigging hardware is then taken to the beach to keep the causeway clear for equipment and personnel movement.

When installing the jacks during pier retrieval, the jacks are attached to the pile caps that remain on the piles after pier construction. The jacks and piles caps are then removed together after lowering the section. The pile caps are released from the jacks and taken to the beach. The jacks are then placed on the pile at their next lowering position and attached to the pile caps there.

Activity Analysis: The removal of the turnbuckles and pile caps where jacks are not used takes place immediately after installation of the jacks is complete. This insures that plenty of personnel and equipment are available for their removal.

Engineering Analysis: To remove the turnbuckles it was sometimes necessary to loosen them by hand because the jacks could not always lift the connected end of a section enough to free them.

Removal of the pile caps required a piece of wire rope to be shackled to the pile cap. This was then hooked by a hydraulic crane or forklift, and the pile cap lifted off.

Recommendations: It is recommended that all personnel concerned with installation and removal of the gimbals be familiar with the process of removing

*This activity is unique to Pier Retrieval.

turnbuckles and pile caps. The completion of jack installation should signal the beginning of the turnbuckle and pile cap removal.

Personnel: The personnel involved in Lift System Mobilization operate in the teams outlined under Pier Retrieval.

Activity: **CAUSEWAY SECTION LOWERING OPERATION**

There are three activities related to the lowering of causeway section(s). They are:

(1) Causeway section separation prior to lowering

(2) Causeway section lowering

(3) Causeway section connection after lowering

Descriptions, analyses, conclusions, recommendations, and personnel requirements are provided for each of these activities.

Activity: **Causeway Section Separation Prior to Lowering**

Description: See "Causeway Separation Prior to Elevating" of Pier Construction for the basics of disconnecting the causeway sections. The male-female connection is designed with a large bottom lip on the female side that prevents the male section from being lowered unless the sections are pushed about 7 inches (18 cm) apart. This is very difficult to accomplish when there is a horizontal curve in the elevated pier and the sections are forced toward each other by the tilt angle of the piles on which they are elevated.

Two methods were tried while attempting to separate Sections No. 2 and 6. First, an LCU with an A-frame was attached by wire rope to the seaward section in an unsuccessful attempt. The separation was accomplished by the second method which consisted of pushing on the end connectors with the bulldozer positioned on the sections. These were the only end connectors to be disconnected to lower the elevated causeway.

Some difficulties were encountered in disconnecting the side connectors because of the horizontal forces exerted on the elevated sections by being elevated on piles that were not vertical. Sections No. 1 and 2 were held in alignment with Sections No. 3 and 4 by wedging shear forces on the side connectors. By pulling on Sections No. 3 and 4 with the winch of the bulldozer located on Sections No. 1 and 2, the sections were realigned laterally, thereby releasing the wedging shear forces on the side connectors. The side connectors were then withdrawn normally.

Activity Analysis: See "Causeway Section Separation Prior to Elevating" of Pier Construction for Activity Analysis.

Engineering Analysis: See "Causeway Section Separation Prior to Elevating" of Pier Construction for additional engineering analysis and conclusions.

Sections must be separated a greater amount in order to lower the section having the male connection first. This situation should be avoided if at all possible by always lowering the section having the female connection first. It could also be avoided by lowering all the sections end-connected.

The elevating procedure discusses raising one end of a section to separate floating sections. This method in reverse is applicable to lowering a section. By lowering one end of a section, the other end will rotate, initiating end connector separation between adjacent sections. This puts the male part of the connection in a better position for the initiation of wedging effects, thereby causing section separation as discussed in "Pier Construction" section of this report.

Recommendations: See "Causeway Section Separation Prior to Elevating" of Pier Construction for recommendations. Lowering the sections while they are end-connected will totally eliminate the disconnecting and connecting problems.

Personnel: Refer to "Causeway Section Separation Prior to Elevating" of Pier Construction for the recommended personnel for disconnecting causeway sections.

Activity: **Causeway Section Lowering**

Description: Sections can be lowered end-connected using only two jacks per section. One method of lowering a section with only two jacks is to set them at opposite corners of the section on either diagonal. Using this method, two end-connected sections (3 and 4) were lowered simultaneously with four jacks. Sections No. 1 and 2 were

lowered simultaneously, but they were not end-connected because of difficulties with the experimental flexor connectors.

The second method of arranging the jacks for lowering was to set two jacks on the end of a section that was connected to another section. Adjacent ends of the two sections were then supported by only two jacks. Using this method, Sections No. 6 through 10 were lowered end-connected, which eliminated the problems of disconnecting and connecting sections. The hydraulic crane was left on Sections No. 1 and 2, which were lowered last. This provided for the removal of the jacks from the sea end of Section No. 6 without having to drive the truck crane over a section that was suspended by only two jacks at the connection. The jacks were transferred by the rough terrain forklift to the connection between Sections No. 7 and 8. After this, the truck crane was used to "leap-frog" the two pairs of jacks down to the beachhead, leaving two jacks at each connection and lowering the sections as far as possible after each movement. Figure B-17 shows the movement of the jacks and the distance each section was lowered between moves.

Installation and removal of the jacks and gimbals were accomplished by the same crews and methods used during elevation. (See "Causeway Section Elevation" of Pier Construction.) Operation of the jacks was basically the same as during elevation, except the sequence of latching was that of the lowering cycle.

When a section reached the water a large amount of jack lift chain was paid out as a safety precaution before releasing the gimbals. The truck crane would then remove the jacks and pile caps and carry the jacks to their next position for reinstallation; the gimbals would simultaneously be disassembled, transferred, and reassembled at the appropriate piles.

Activity Analysis: The method of lowering the causeway sections is straightforward, and no apparent problems were evident. Because it is the same basic procedure as elevating, the crews and equipment are the same.

Lowering the sections end-connected was the fastest and most convenient method, because it avoids the problems of disconnecting and connecting sections and allows easy, continuous access to the sections being lowered.

Engineering Analysis: See "Causeway Section Elevation Engineering Analysis" of Pier Construction for a summary of the problems involved in the use of the lift system for both elevation and lowering.

The forces developed by the jacks during lowering as compared to elevation can be increased substantially to allow two jacks to lower a section rather than the four needed to elevate it. The section is lifted less than 1 inch (2.6 cm) to unload the lower latches as required for latch retraction and lowering. A lift of 1 inch (2.5 cm) can be done slowly, developing a maximum jack static capacity more than 50 tons (45.4 Mg) as opposed to 35 tons (32 Mg) for regular lifting rates.

Recommendations: See "Causeway Section Elevation" of Pier Construction for suggestions on semi-automated jacking systems and manual override for each jack.

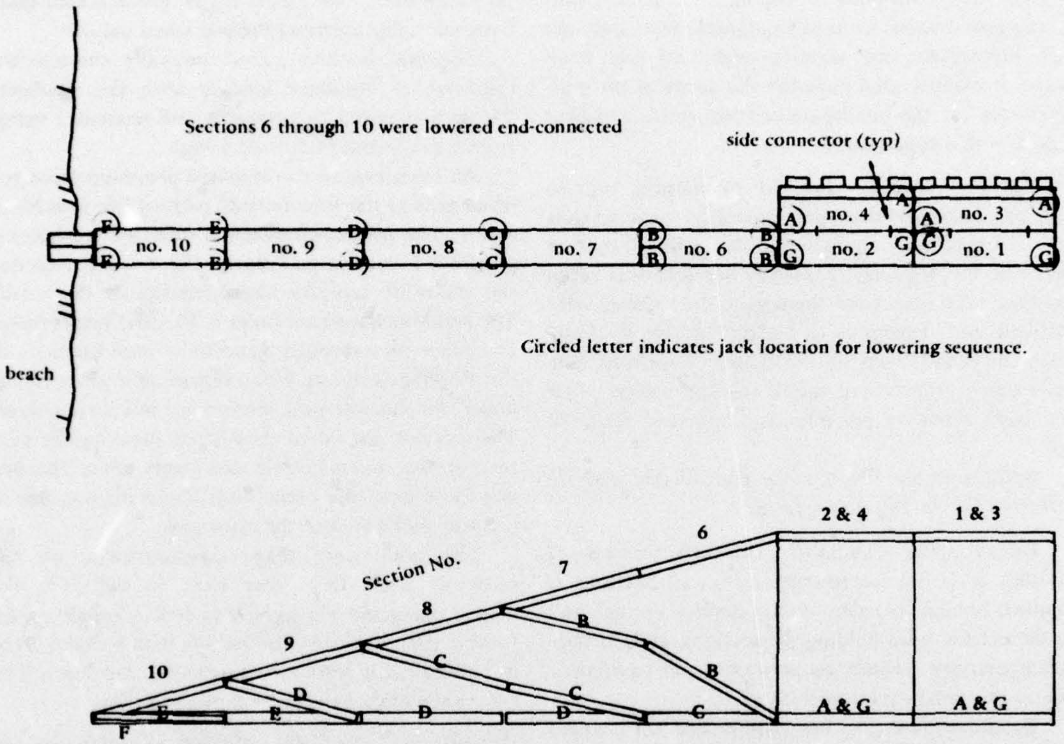
Methods should be investigated for lowering all the sections while end-connected.

Personnel: The personnel used for causeway section lowering are the same as those used for section elevation. A list of the personnel can be found in "Causeway Section Elevation" of Pier Construction.

Activity: **Causeway Section Connection After Lowering**

Description: Once the causeway sections are floating, those sections that were not lowered end-connected must be reconnected before the crane can drive onto them to remove the jacks and pull the piles. It was necessary, therefore, to make connections between Sections No. 1, 2, and 6.

Several methods were used to get the connections completed, including attaching a warping tug to each side of Section No. 2 and pulling it away from Section No. 6. This maneuver was discontinued because it jostled the jacks that were still on the piling severely. Pushing with bulldozers was also tried, but track slippage prevented the development of enough force and the wooden deck reinforcement was damaged. The connection was finally completed by removing the beach ramps and using two bulldozers to pull Sections No. 6 through 10 onto the beach. At the same time, the wave action lifted the joint, and the connectors slipped together.



Order of Lowering	Lowering	Location of Sections After Each Lowering
A	1st	3 & 4 in water
B	2nd	end of 6 touches water
C	3rd	6 in water, end of 7 in water
D	4th	6, 7, & 8 in water, end of 9 in water
E	5th	6, 7, 8, & 9 in water, end of 10 in water
F	6th	6, 7, 8, 9, & 10 in water, end of 10 on beach
G	7th	1 & 2 in water

Figure B-17. Lowering the elevated causeway at Coronado.

The connection between Sections No. 1 and 2 was completed by a combination of wave action and crane movement near the connection which forced the connectors together.

The time consumed in making these connections was approximately 5 hours. Equipment used included two bulldozers, two warping tugs, and one truck crane. Personnel used included the crews of the tugs, operators for the bulldozers and the crane, and four riggers with a supervisor.

Activity Analysis: The use of warping tugs to pull causeway sections apart presented great dangers to personnel and equipment. The relative motion between the tugs and causeway sections was often extreme. The lines from the tugs to the sections were difficult and dangerous to attach because of inadequate bitts and cleats on the causeway sections. The causeway sections were shook to such a degree that the jacks tilted on the piles and appeared ready to fall.

Bulldozers are much more controllable and are effective for making connections.

Engineering Analysis: The effectiveness of floating craft for connecting causeway sections is minimal because (1) they do not develop enough pull to deflect the piles holding the sections, and (2) they create extreme hazards to personnel and equipment due to the violent motions created.

Bulldozers are the best equipment for maneuvering sections to make end connections. They can be used to push and pull or as deadweights when necessary. Wave action is also a valuable tool.

Recommendations: The most complete solution to the problem of end connecting is to lower all sections end-connected. If an end connection must be made, the use of bulldozers is recommended to push, pull, or act as deadweights on the causeway sections. Floating craft, such as warping tugs, present dangers to both men and equipment and should not be used for section connection.

Activity: **PULLING OF PILES**

Description: Once the causeway is floating, the piles are prepared for pulling. The pulling is done by the truck crane, which is positioned (outriggers set) near each pile.

The pile is prepared by cutting holes through the pile and inserting a 3-inch (7.67-cm) diameter pin through the pile. Next a chain is wrapped around the pile under the pin, shackled, and then connected to the crane hook (See Figure B-18). The shackled chain loop will tighten around the pile when pulled.

The pile is then pulled vertically through the spudwell to minimize binding with the spudwell. The pull required to overcome soil resistance varied from 5 to 25 tons (4.5 to 22.5 Mg).

An exception to this standard procedure occurred when pulling the four outside piles of Sections No. 3 and 4. The horizontal distance from the truck crane positioned on elevated Sections No. 1 and 2 exceeded the reach/lift capacity characteristics of the crane. The solution was to cut holes in the four outside piles and place pins through those holes near the deck of the floating sections. Wood blocks were then placed under the pins when the section was in a wave trough. The sections were then wave-lifted, breaking the piles free of the ocean bottom sediments. Once the pile was loose from the ocean floor, the crane was able to lift it up and out onto the causeway.

The piles were than laid lengthwise on the causeway deck. Once they were on the deck, the looped chain and pin were removed. A rough terrain forklift then hooked onto the pile with a chain, lifted it, and pulled it from the causeway to the beach. The crane then moved to the next pile position.

Activity Analysis: The pulling of piles can be generally a safe and efficient process when a normal amount of care is taken. Unusual circumstances might present unforeseen dangers because of the loads and crane/pile relative movements involved. (The crane is sitting on a floating section moving with that section.) The personnel risks can be reduced considerably by keeping the personnel in the area at a minimum.

Engineering Analysis: Problems involved with pile pulling included:

(1) Difficulty in pulling piles on the far side of an adjacent section due to limited reach of the crane.

(2) Danger to personnel installing pins and blocks used to wave-lift piles that the crane could not pull.

(3) Danger to personnel from swinging piles when trying to lay them on the deck.

(4) Difficulty in pulling piles through spudwells that have been damaged.

Solutions to these problems consist of a combination of methods and personnel skill.

The pulling of piles from across a section, laying piles onto the deck, and pulling piles that are damaged are operations that depend largely on the skill of the crane operator. A skilled operator working with trained personnel can eliminate many dangers by exercising a normal amount of caution.

Piles pulled from a distance must be wave-lifted by the pin and block method previously described. This method can be improved by providing longer pins and large blocks of hard wood.

A pile that is damaged below the spudwell may fit through the spudwell by pulling it at an angle. A pile that cannot be pulled in this manner may have to be cut above the spudwell and the remainder dropped to the ocean floor.

Recommendations: It is recommended that the personnel involved with the pile pulling operation be well trained in their safety responsibilities, especially the crane operator and the riggers. Noninvolved personnel should be kept clear of the area at all times.

Personnel: The number of personnel involved varied during actual pile pulling operations with the following as the optimum crew.

	Recommended	
Type of Personnel	No.	Rate
Supervisor	1	EOC
Signalman	1	EO2
Crane Operator	1	EO2
Forklift Operator	1	EO3
Welder	1	SWCN
Riggers	5	SN/SR

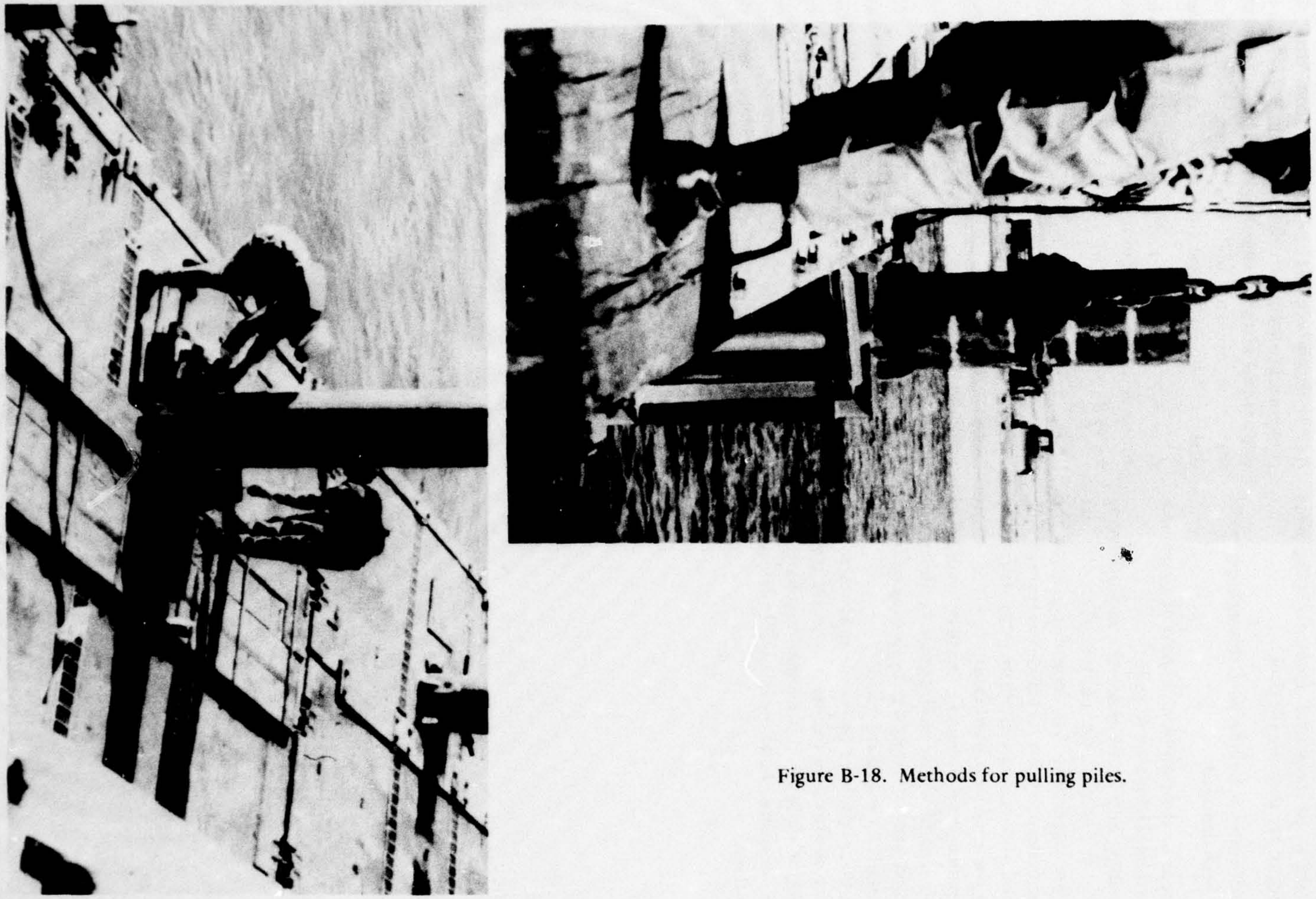


Figure B-18. Methods for pulling piles.

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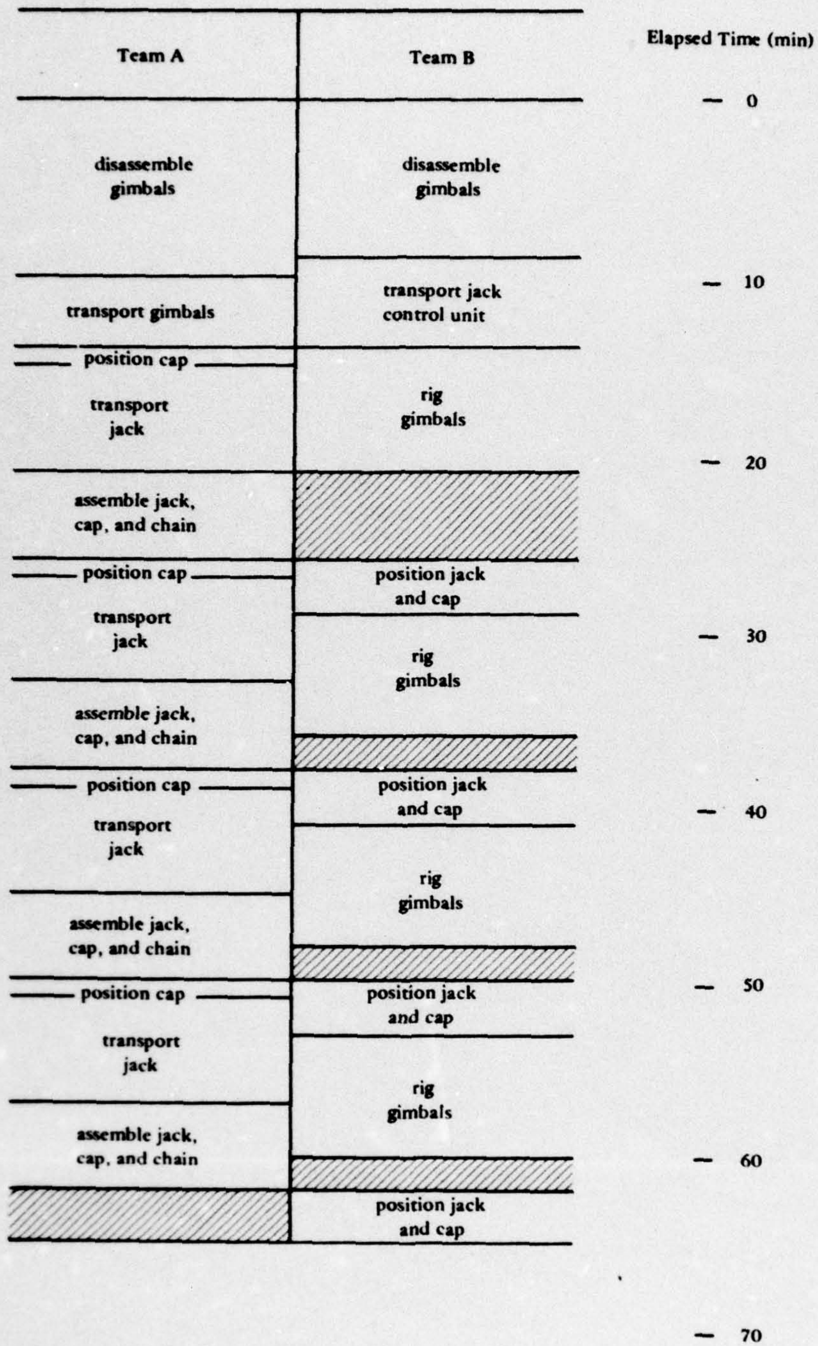
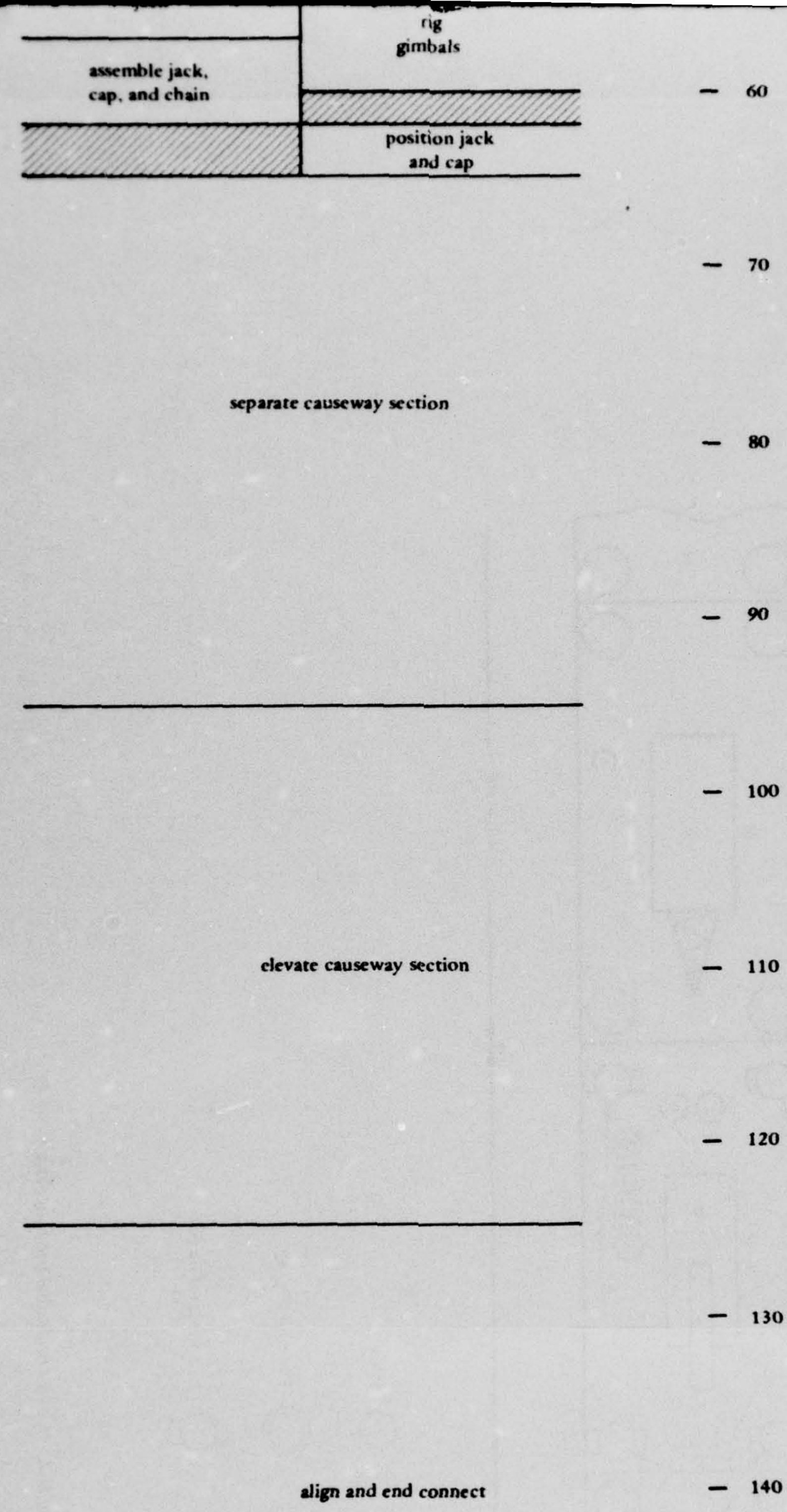
Appendix C

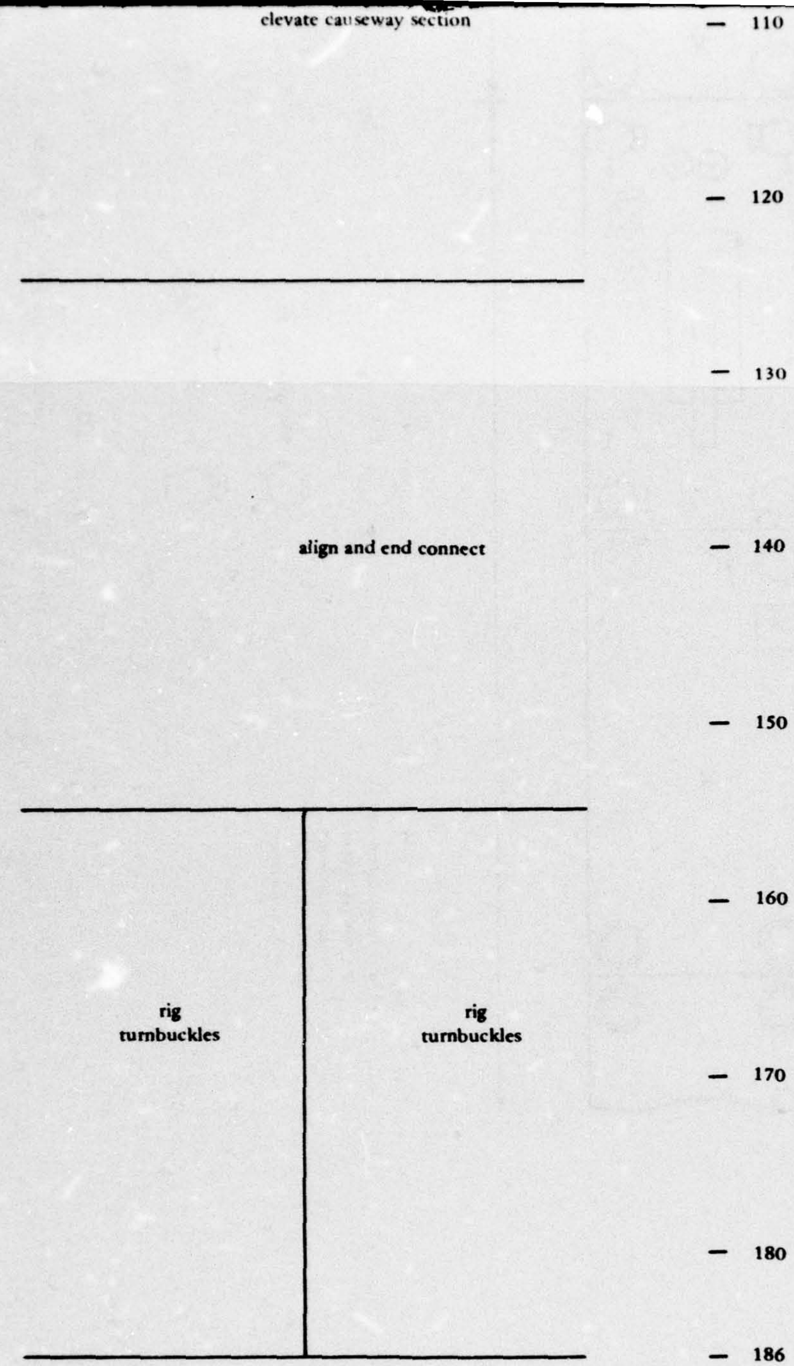
MULTIPLE ACTIVITIES AND INITIAL CONDITION CHARTS FOR PIER CONSTRUCTION

The pier construction process requires several tasks to be performed simultaneously for optimum overall effectiveness of the pier construction teams. These tasks are usually repeated as each causeway section or group of causeway sections is elevated, thereby requiring careful coordination of all activities. The coordination of the activities depends on the number of personnel/teams available to perform the tasks. Multiple activity and initial condition charts (Figures C-1 through C-7) have been prepared that are based on the Coronado tests; these charts describe coordinated activities and initial conditions for several combinations of teams.


Team A
Team B
Elapsed Time (min)
0
10
20
30
40
50
60
70
disassemble gimbals
disassemble gimbals
transport gimbals
transport jack control unit
position cap
transport jack
rig gimbals
assemble jack, cap, and chain
position cap
position jack and cap
transport jack
rig gimbals
assemble jack, cap, and chain
position cap
position jack and cap
transport jack
rig gimbals
assemble jack, cap, and chain
position cap
position jack and cap
transport jack
rig gimbals
assemble jack, cap, and chain
position jack and cap



rig
gimbals
assemble jack, cap, and chain
position jack and cap
separate causeway section
elevate causeway section
align and end connect
60
70
80
90
100
110
120
130
140



*For the initial conditions to this activity chart refer to Figure C-2.

Figure C-1. Multiple activity chart – Causeway lifting using two teams and four jacks.

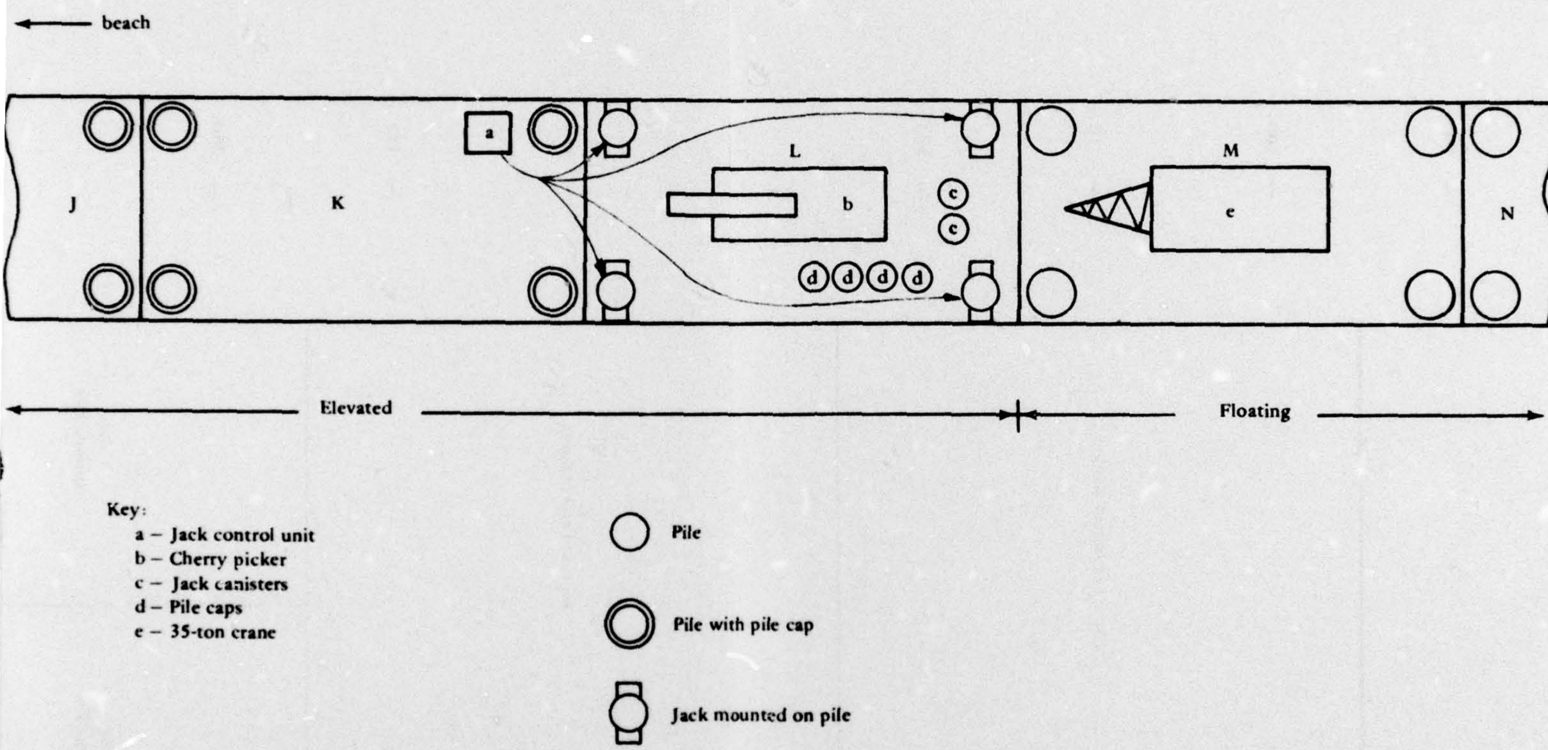
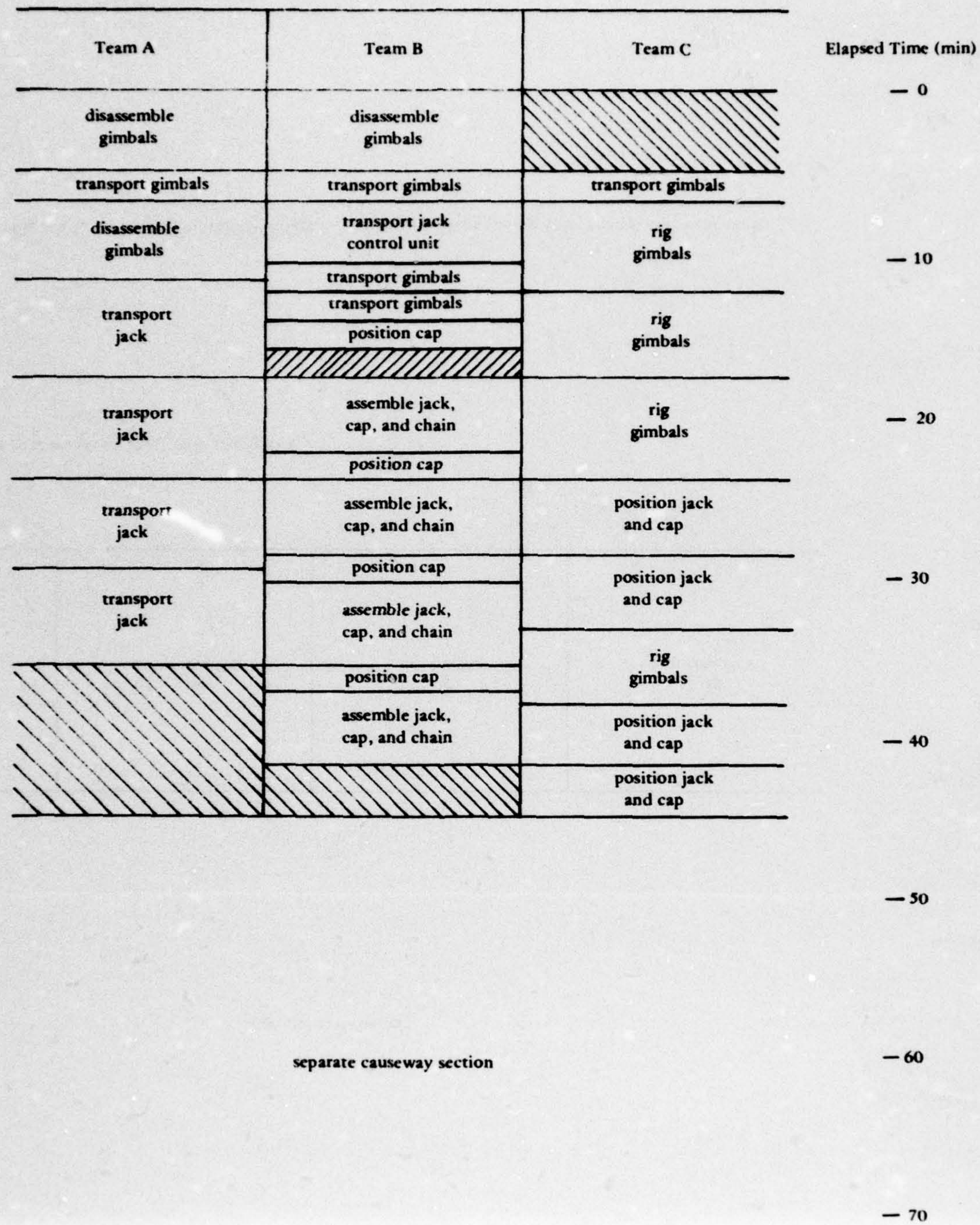
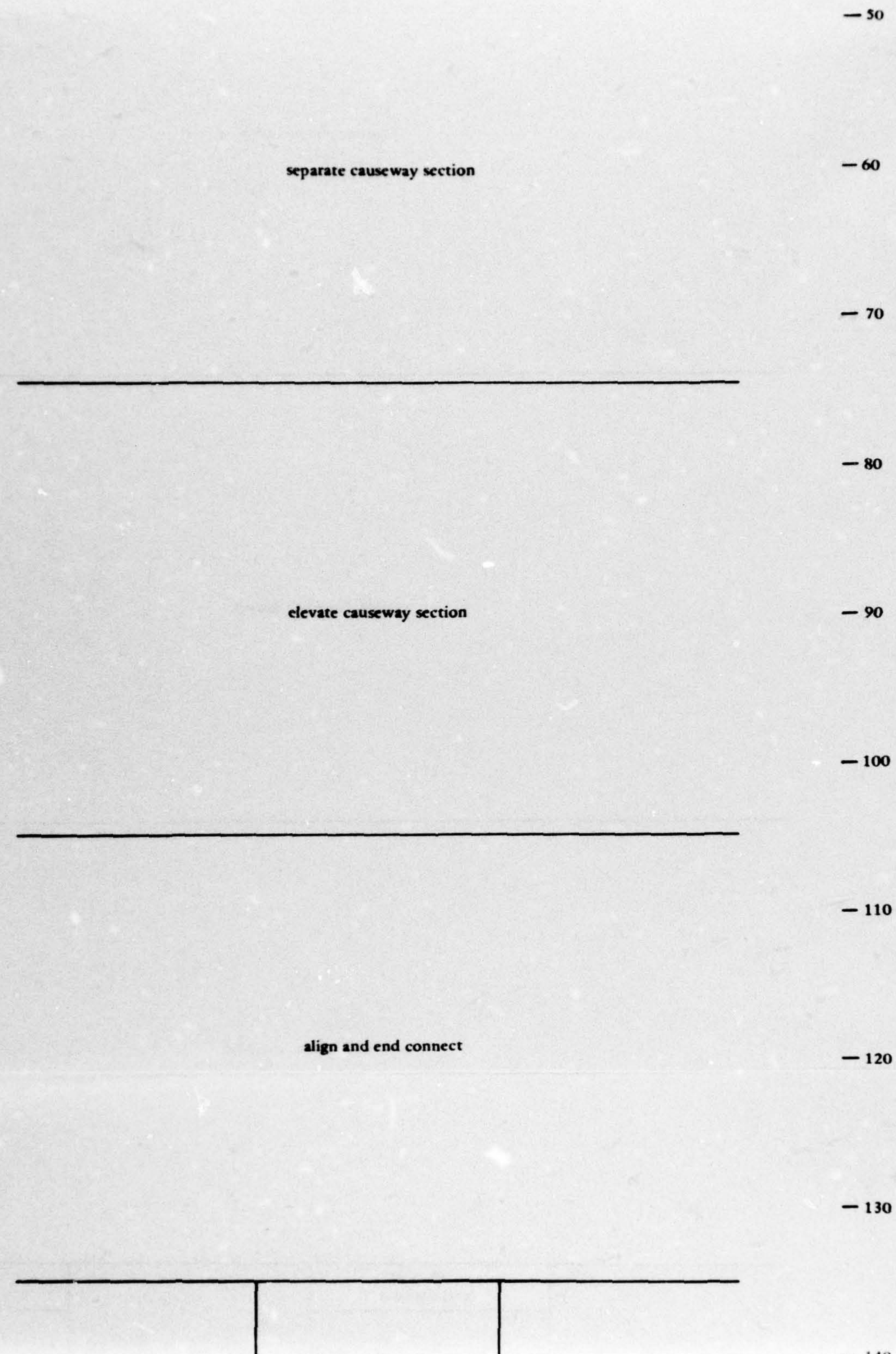
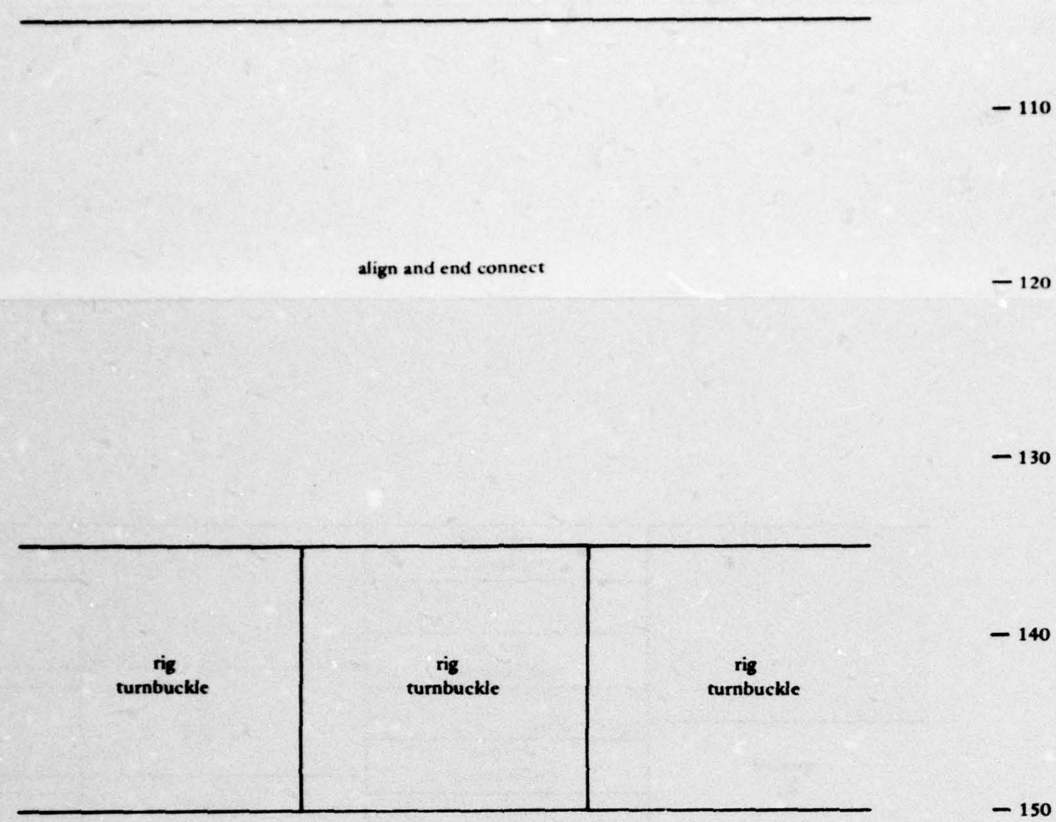


Figure C-2. Initial conditions for four-jack system.


Team A
Team B
Team C
Elapsed Time (min)
— 0
— 10
— 20
— 30
— 40
— 50
— 60
— 70
disassemble gimbals
disassemble gimbals
transport gimbals
transport gimbals
transport gimbals
disassemble gimbals
transport jack control unit
rig gimbals
transport gimbals
transport gimbals
transport jack
position cap
rig gimbals
transport jack
assemble jack, cap, and chain
rig gimbals
position cap
transport jack
assemble jack, cap, and chain
position jack and cap
position cap
transport jack
assemble jack, cap, and chain
position jack and cap
position cap
rig gimbals
assemble jack, cap, and chain
position jack and cap
position jack and cap
separate causeway section

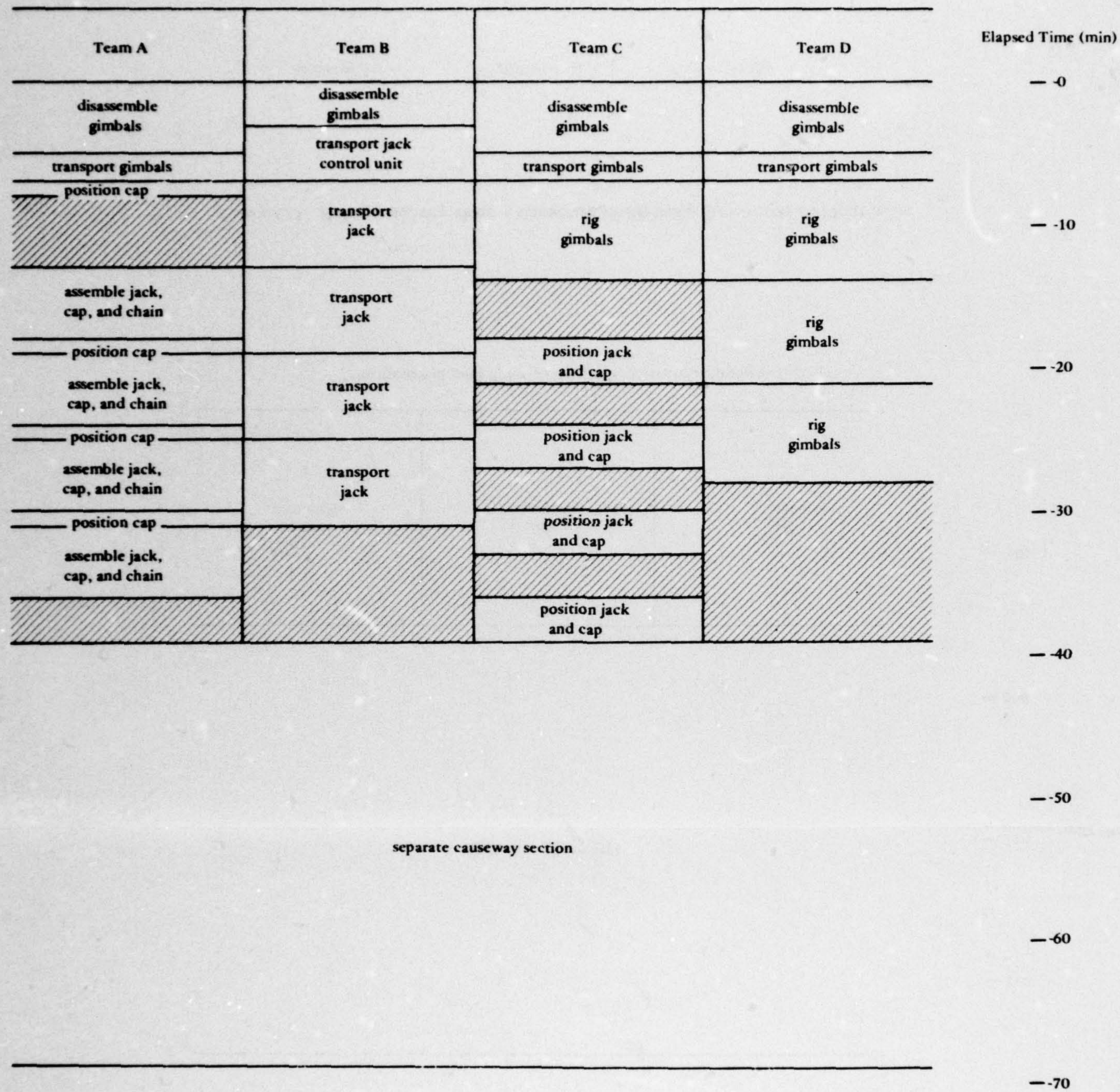


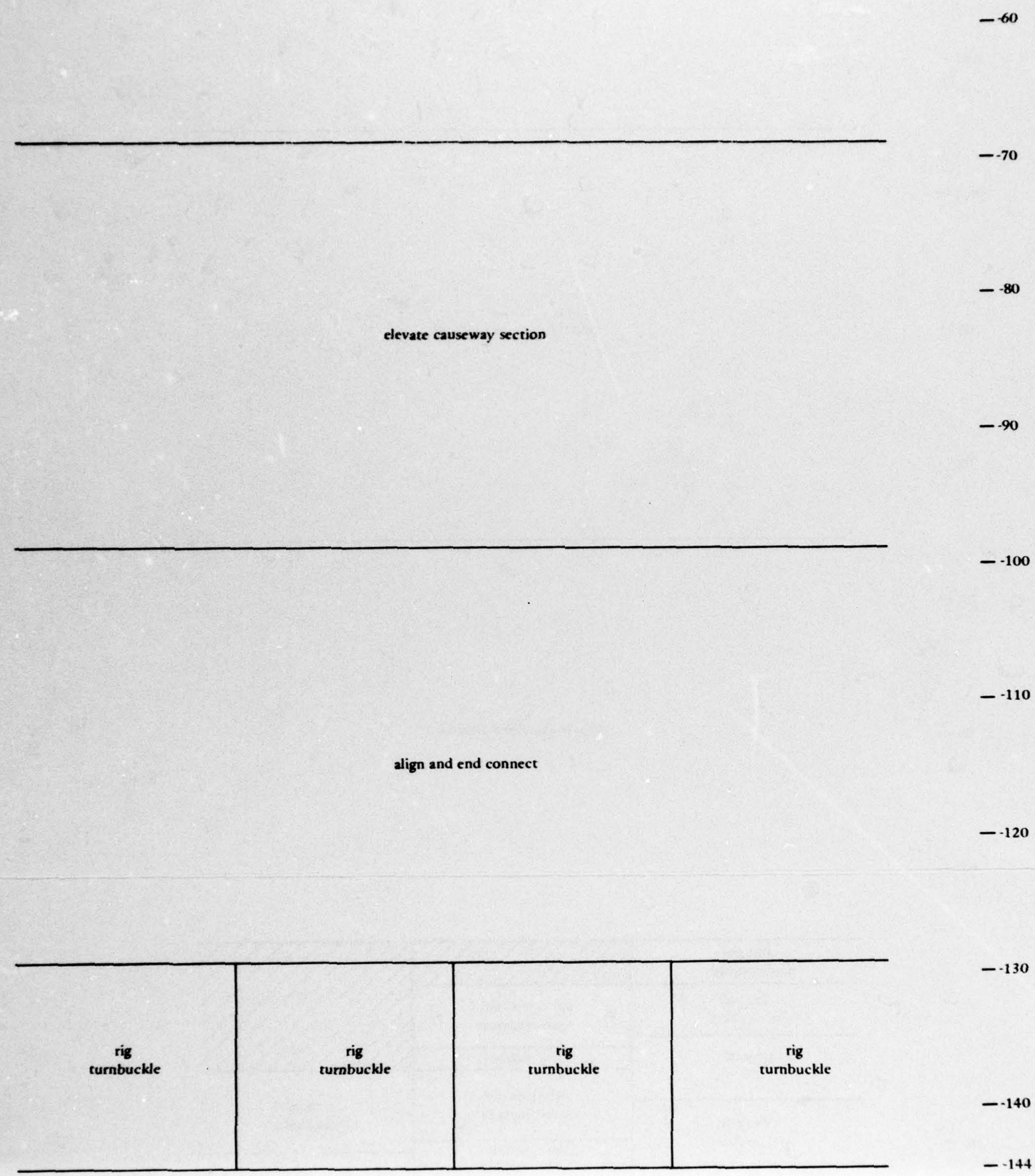
— 50
separate causeway section
— 60
— 70
— 80
elevate causeway section
— 90
— 100
— 110
align and end connect
— 120
— 130
— 140

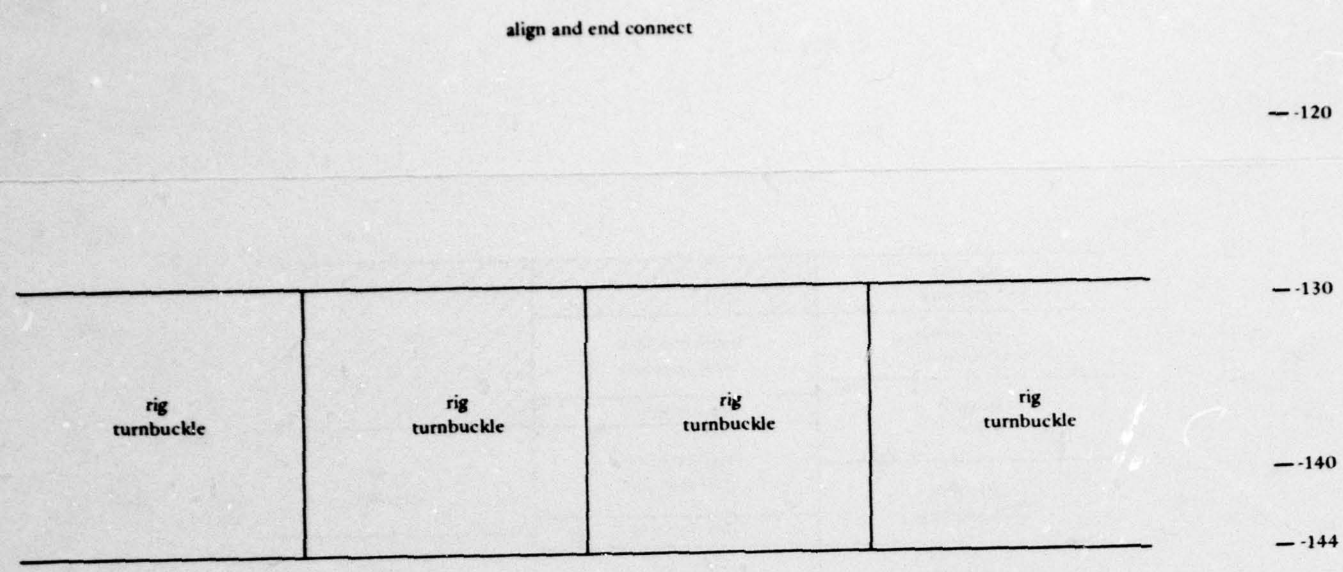


*For the initial conditions to this activity chart refer to Figure C-2.

Figure C-3. Multiple activity chart – Causeway lifting using three teams and four jacks.

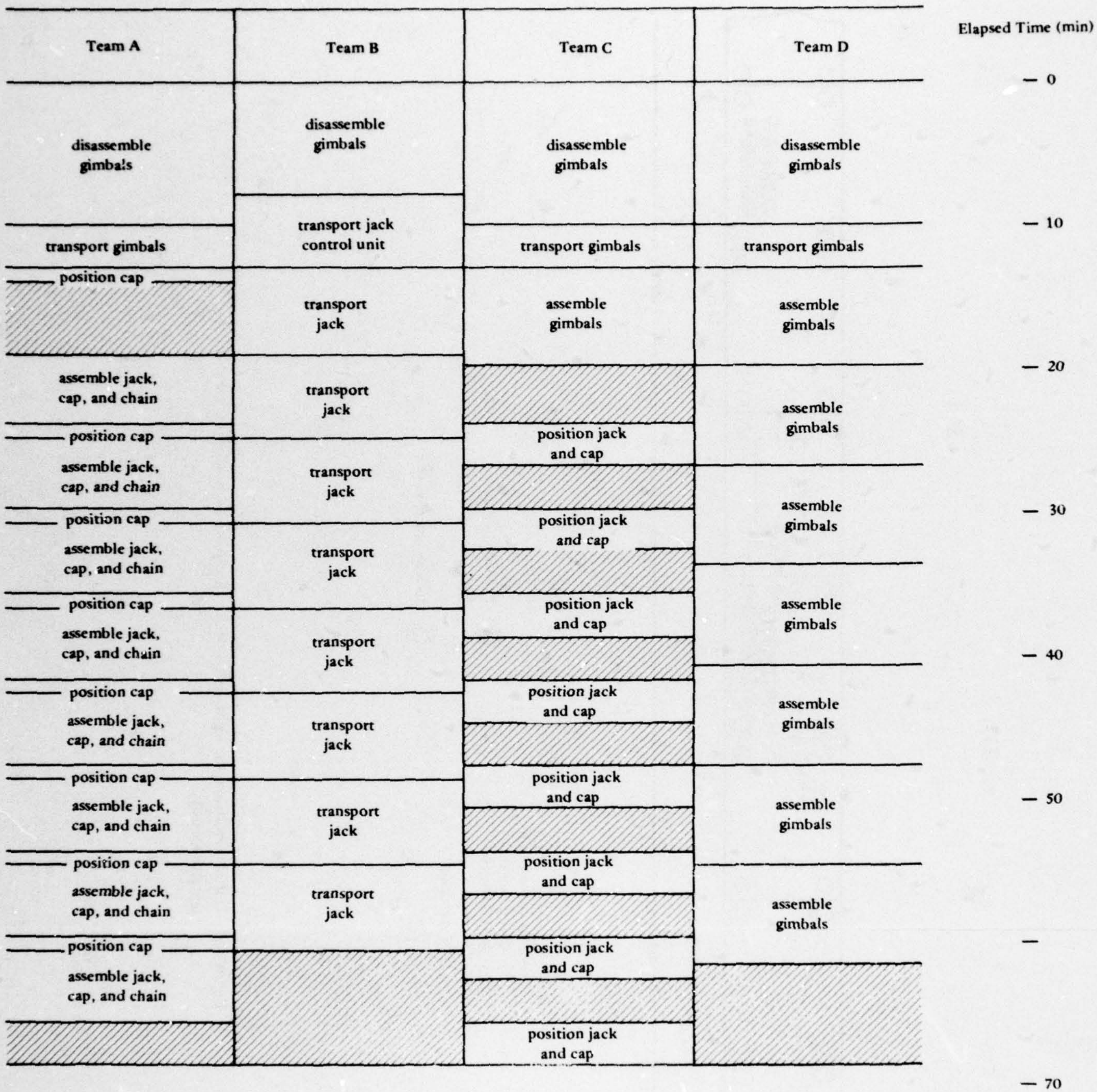

Team A
Team B
Team C
Team D
Elapsed Time (min)
disassemble gimbals
transport gimbals
position cap
assemble jack, cap, and chain
position cap
assemble jack, cap, and chain
position cap
assemble jack, cap, and chain
position cap
assemble jack, cap, and chain
disassemble gimbals
transport jack control unit
transport jack
transport jack
transport jack
transport jack
disassemble gimbals
transport gimbals
rig gimbals
position jack and cap
position jack and cap
position jack and cap
position jack and cap
disassemble gimbals
transport gimbals
rig gimbals
rig gimbals
rig gimbals
separate causeway section
-0
-10
-20
-30
-40
-50
-60
-70

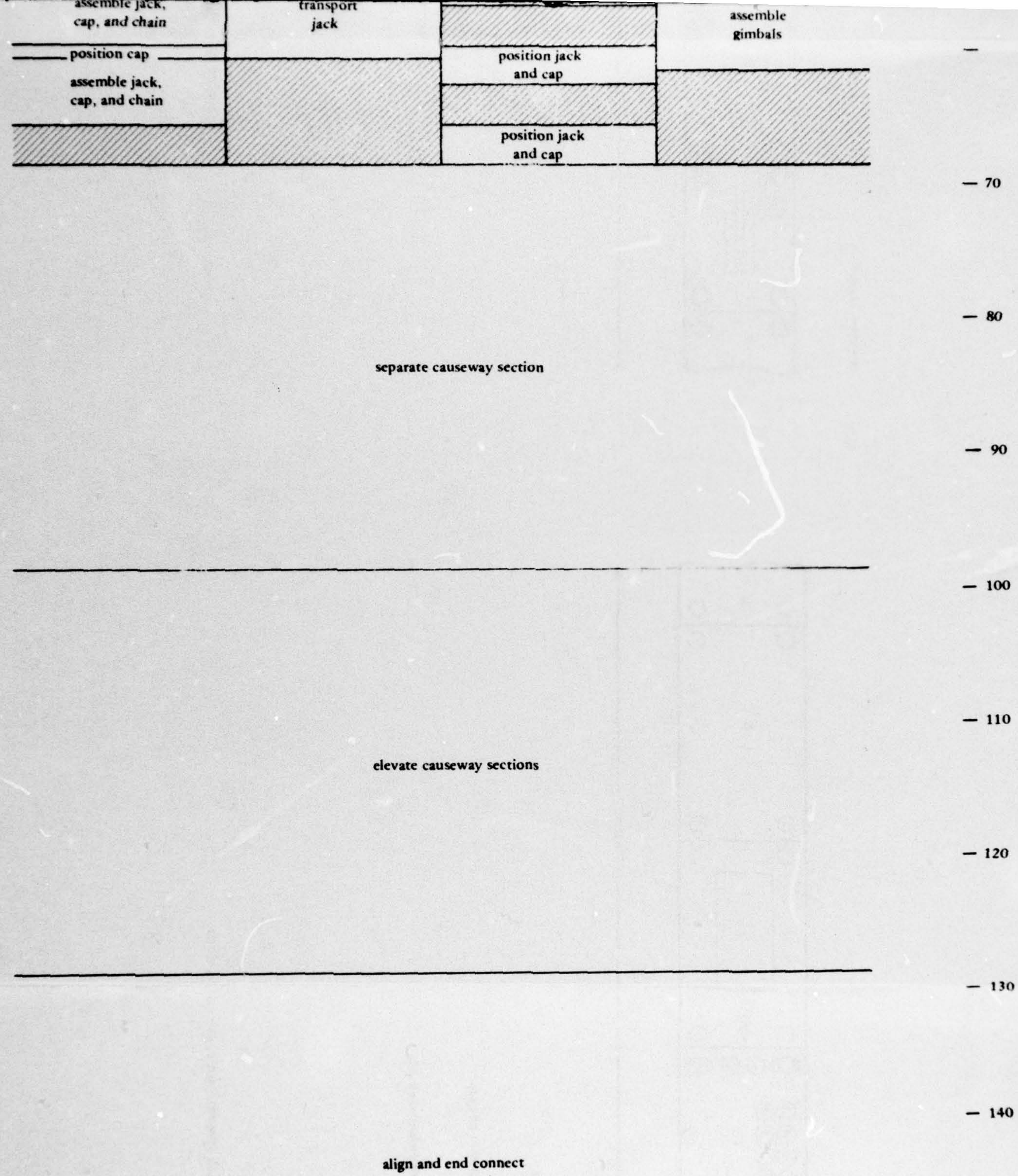

-60
-70
elevate causeway section
-80
-90
-100
-110
align and end connect
-120
-130
rig turnbuckle
rig turnbuckle
rig turnbuckle
rig turnbuckle
-140
-144



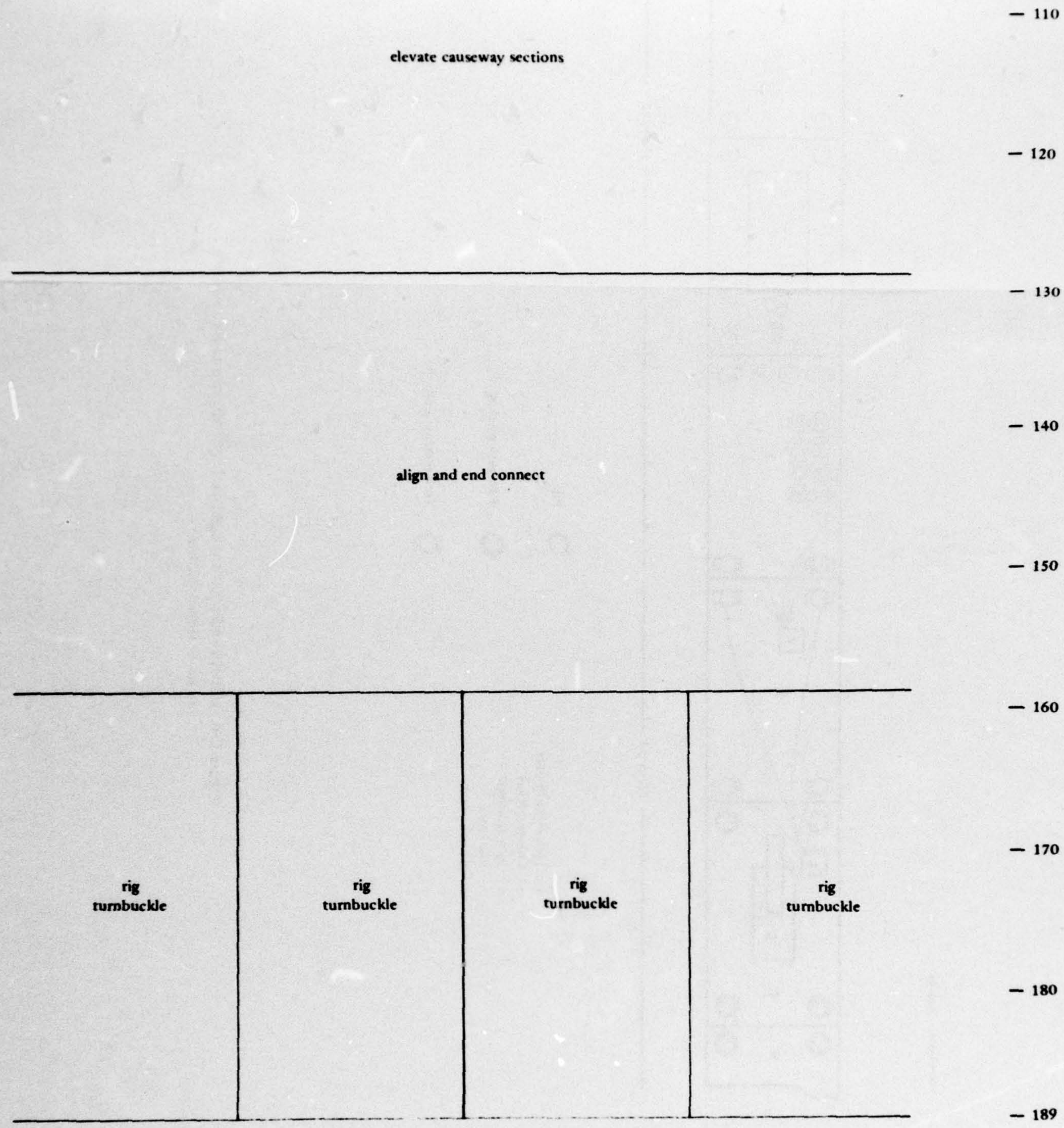
*For the initial conditions to this activity chart refer to Figure C-2.

Figure C-4. Multiple activity chart – Causeway lifting using four teams and four jacks.


Team A
Team B
Team C
Team D
Elapsed Time (min)
0
10
20
30
40
50
70
disassemble gimbals
transport gimbals
position cap
assemble jack, cap, and chain
transport jack control unit
transport jack
assemble gimbals
position jack and cap

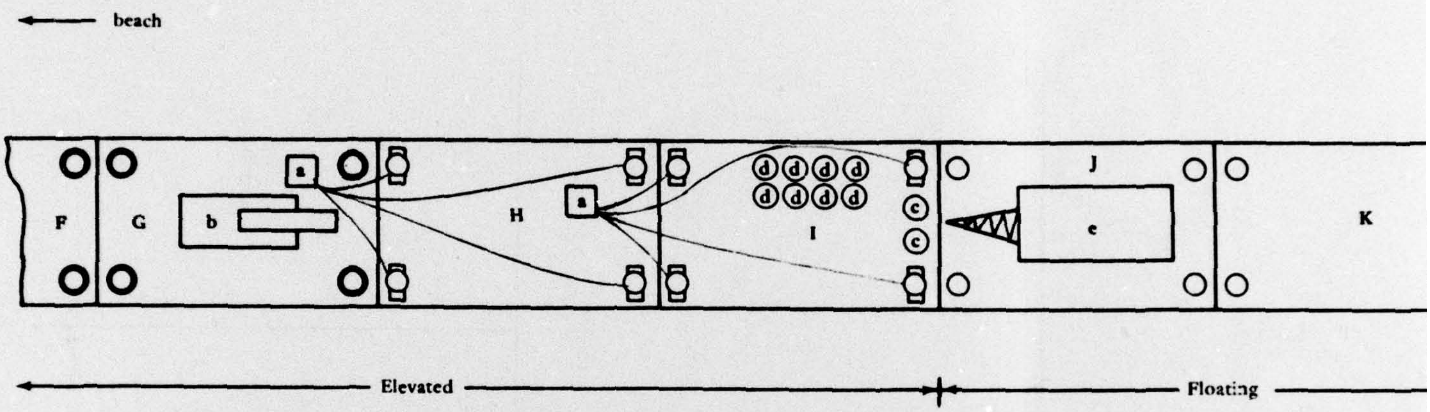


assemble jack, cap, and chain
position cap
assemble jack, cap, and chain
transport jack
position jack and cap
position jack and cap
assemble gimbals
70
80
90
100
110
120
130
140
separate causeway section
elevate causeway sections
align and end connect



*For the initial conditions to this activity chart refer to Figures C-6 and C-7.

Figure C-5. Multiple activity chart – Causeway lifting using four teams and eight jacks.



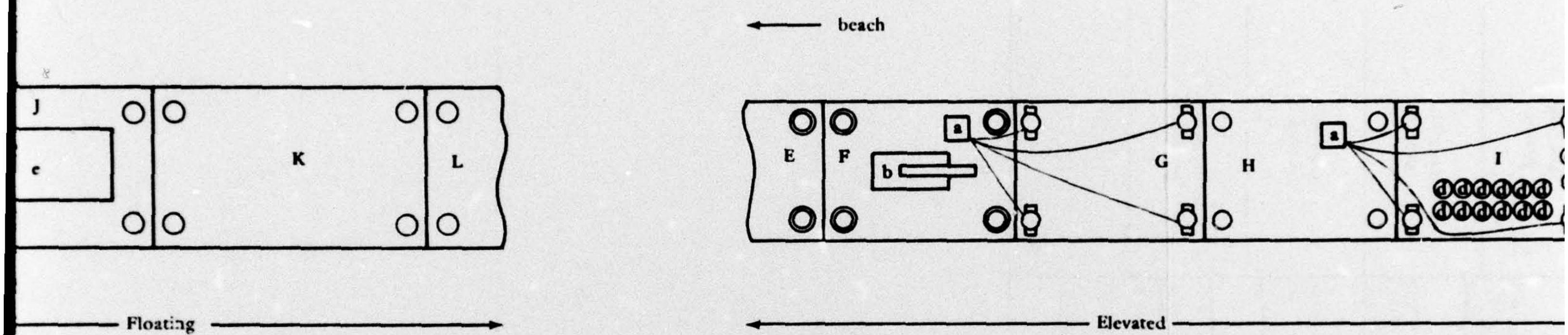
Key:
a – Jack control unit
b – Cherry picker
c – Jack canisters
d – Pile caps
e – 35-ton crane

Pile

Pile with pile cap

Jack mounted on pile

Figure C-6. Initial conditions for eight-jack system; two causeway sections elevated simultaneously.



Key:
a – Jack control unit
b – Cherry picker
c – Jack canisters
d – Pile caps
e – 35-ton crane

P

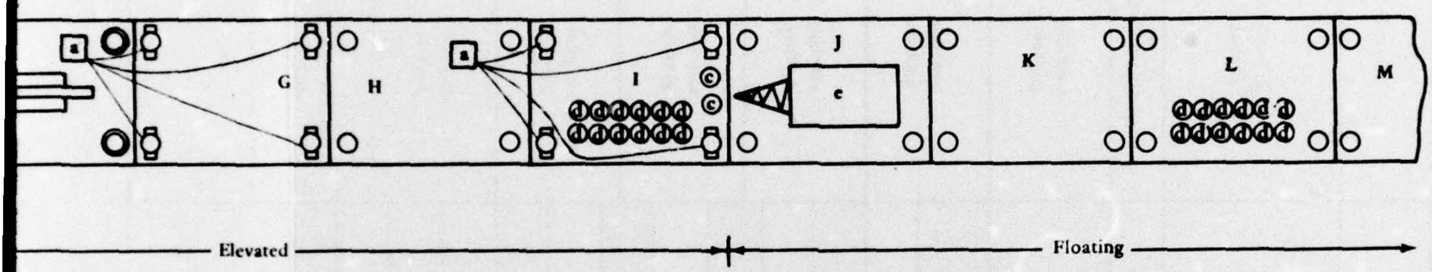
P

J

ns

Figure C-7. Initial conditions for eight-jack system;
simultaneously.

7



Key:
- a – Jack control unit
- b – Cherry picker
- c – Jack canisters
- d – Pile caps
- e – 35-ton crane

Pile

Pile with pile cap

Jack mounted on pile

Figure C-7. Initial conditions for eight-jack system; three causeway sections elevated simultaneously.

3

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NAVTECHTRACEN SCE, Pensacola FL
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NAVWPNSUPPCEN Code 09 (Boennighausen) Crane IN
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NCBC CEL (CAPT N. W. Petersen), Port Hueneme, CA; CEL AOIC Port Hueneme CA; Code 10 Davisville, RI; Code 155, Port Hueneme CA; Code 155, Port Hueneme CA
NCR 20, Commander; FWD 30th CDR Diego Garcia Island
NMCB 5, Operations Dept.; 74, CO
NTC Code 54 (ENS P. G. Jackel), Orlando FL; OICC, CBU-401, Great Lakes IL
NUSC Code 131 New London, CT
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UNIVERSITY OF DELAWARE Newark, DE (Dept of Civil Engineering, Chesson)
UNIVERSITY OF HAWAII HONOLULU, HI (SCIENCE AND TECH. DIV.)
UNIVERSITY OF ILLINOIS Metz Ref Rm, Urbana IL; URBANA, IL (NEWARK)
UNIVERSITY OF MICHIGAN Ann Arbor MI (Richart)
UNIVERSITY OF NEBRASKA-LINCOLN Lincoln, NE (Ross Ice Shelf Proj.)
UNIVERSITY OF WASHINGTON SEATTLE, WA (OCEAN ENG RSCH LAB, GRAY); Seattle WA (E. Linger)
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AUSTRALIA Dept. PW (A. Hicks), Melbourne
BECHTEL CORP. SAN FRANCISCO, CA (PHELPS)
BELGIUM HAECON, N.V., Gent
CANADA Mem Univ Newfoundland (Chari), St Johns; Surveyor, Nenninger & Chenevert Inc., Montreal
CF BRAUN CO Du Bouchet, Murray Hill, NJ
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DRAVO CORP Pittsburgh PA (Giannino)
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PACIFIC MARINE TECHNOLOGY LONG BEACH, CA (WAGNER)
PORTLAND CEMENT ASSOC. SKOKIE, IL (CORELY); Skokie IL (Rsch & Dev Lab, Lib.)
RAYMOND INTERNATIONAL INC. CHERRY HILL, NJ (SOILTECH DEPT)
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SHELL OIL CO. Houston TX (R. de Castongrene)
SWEDEN GeoTech Inst; VBB (Library), Stockholm
UNITED KINGDOM Cement & Concrete Assoc (G. Somerville) Wexham Springs, Slou; Cement & Concrete Assoc. (Lit. Ex), Bucks; D. New, G. Maunsell & Partners, London; J. Derrington, London; Library, Bristol; Taylor, Woodrow Constr (014P), Southall, Middlesex; Univ. of Bristol (R. Morgan), Bristol
WESTINGHOUSE ELECTRIC CORP. Annapolis MD (Oceanic Div Lib, Bryan)
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